Improvement Programme for England's Natura 2000 Sites (IPENS) – Planning for the Future IPENS008d

Pollution Risk Assessment and Source Apportionment: Camel Catchment

River Camel Special Area of Conservation (SAC)

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Foreword

The **Improvement Programme for England's Natura 2000 sites (IPENS)**, supported by European Union LIFE+ funding, is a new strategic approach to managing England's Natura 2000 sites. It is enabling Natural England, the Environment Agency, and other key partners to plan what, how, where and when they will target their efforts on Natura 2000 sites and areas surrounding them.

As part of the IPENS programme, we are identifying gaps in our knowledge and, where possible, addressing these through a range of evidence projects. The project findings are being used to help develop our Theme Plans and Site Improvement Plans. This report is one of the evidence project studies we commissioned.

Water pollution has been identified as one of the top three issues in all Natura 2000 rivers. It also affects many terrestrial and some marine and coastal Natura 2000 sites.

Diffuse water pollution is the release of potential pollutants from a range of activities that individually may have little or no discernable effect on the water environment, but at the scale of a catchment can have a significant cumulative impact. The sources of diffuse water pollution are varied and include sediment run-off from agricultural land.

The River Camel and its main tributaries have been designated as both a Special Area of Conservation (SAC) and a Site of Special Scientific Interest (SSSI) due to their diverse assemblages of in-stream aquatic and marginal flora and fauna. The SAC/SSSI is currently classified as being in unfavourable recovering condition. The findings of this report have been used to develop a Diffuse Water Pollution Plan for the catchment that will help to improve the water quality and the condition of the site.

Diffuse Water Pollution Plans are a joint Natural England and Environment Agency tool used to plan and agree strategic action in relation to diffuse pollution at the catchment-scale. They are the most frequently identified mechanism for improving water quality on Natura 2000 sites.

This study is one of four produced by the IPENS project "Meeting local evidence needs to enable Natura 2000 Diffuse Water Pollution Plan Delivery".

Natural England Project officer: Russ Money, **russ.money@naturalengland.org.uk**

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Published by:

Westcountry Rivers Ltd.
Rain Charm House, Kyl Cober Parc, Stoke Climsland, Callington, Cornwall, PL17 8PH.
Tel: 01579 372140; Email: info@wrt.org.uk; Web: www.wrt.org.uk

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Executive summary

The River Camel and its main tributaries have been designated as both a ***Special Area of Conservation*** (SAC) and ***Site of Special Scientific Interest*** (SSSI) due to their diverse assemblages of in-stream aquatic and marginal flora and fauna. As such, the River Camel SAC/SSSI must meet certain biological, physical and chemical standards, to maintain and where necessary improve its ecological integrity and prevent any deterioration.

The River Camel SAC/SSSI is currently classified as 'unfavourable recovering' (Natural England, 2012). Consequently, a 'diffuse water pollution plan' (DWPP) must be carried out to assess pressures and management options for the River Camel SAC/SSSI. The outputs from this report will feed into the DWPP from the River Camel.

As the River Camel SAC/SSSI receives water drained from the wider catchment, we have carried-out a full catchment scale investigation. Our investigation incorporates detailed water quality analysis and presents a suite of model outputs, including SCIMAP, SAGIS, SIMCAT and FARMSCOPER.

This report and previous investigations have identified specific pressures from suspended sediments (SS) and phosphorus (P) within the Camel catchment.

1. Introduction

Special Areas of Conservation (***SACs***) and ***Special Protection Areas*** (***SPAs***), collectively known as ***Natura 2000*** sites, are protected under European legislation for their wildlife and habitats. Under the Water Framework Directive, SACs and SPAs are required to be in favourable or improving condition by 2015. However, due to the high percentages of SACs and SPAs affected by diffuse pollution, the ***Improvement Programme for England's Natura 2000 Sites*** (***IPENS***) has identified and prioritised the need for ***Diffuse Water Pollution Plans*** (***DWPPs***) to be devised on a site-by-site basis, where ***Natura 2000*** sites are failing to meet conservation objectives and where pollution represents a threat to their long term integrity. In August 2013, 43 Natura 2000 sites were identified as requiring DWPPs. DWPPs are to provide starting points for a sequential approach to integrated diffuse water pollution management in identified sites.

Natural England has engaged the Westcountry Rivers Limited to develop a catchment wide pollution risk and source apportionment assessments, in support of the Camel catchment DWPP. The objective of these assessments is to undertake a detail review of the available evidence and using visualisation techniques present this information so it is more accessible and thus better able to inform the DWPP and any potential future catchment management initiatives.

Specific objectives of these assessments are to provide: (1) a targeted and fully costed catchment intervention strategy designed to achieve the most significant improvements in water quality using the most cost-effective and resource-efficient approach; (2) an assessment of potential implications of future housing and employment growth in the catchment, in terms of deterioration and the ability to meet conservation objectives; and (3) clear spatial visualisations and representation of all data and evidence collected.

The River Camel and its major tributaries have been designated as both an SAC and SSSI due to their diverse assemblages of in-stream aquatic and marginal flora and fauna. In particular, the site hosts Annex II species (Salmon, Bullhead and Otter) and Annex I habitats (European dry heaths, old sessile oak woods and alluvial forests which are protected under the EC Directive on the Conservation of Habitats and Wild Flora and Fauna; and ranunculus, which is a UK Biodiversity Action Plan (UKBAP) species. The River Camel SAC/SSSI includes the upper and lower River Camel and a number of larger tributaries, including the De Lank River, the Upper River Ruthern and the Demelza Stream (Ruthern). The Camel River SAC/SSSI flows through upland moor and predominately lowland agricultural land-use, draining a large portion of North Cornwall.

2. Methodology

Our approach has been tailored to the Camel catchment taking into consideration its size, the available data and diffuse pollution challenges upstream of SAC and SSSI.

Presentation of existing information regarding current natural habitats, SAC/SSSI and Water Framework Directive (WFD) classifications provides an initial starting point of this assessment. These catchment classifications provide background information to our detailed analysis of empirical data and evidence. Existing standards and requirements for SACs, SSSIs and WFD objectives have been detailed, along with an examination of the methods used to derive existing classifications.

2.1. Pollutant source apportionment

In order to develop tailored and targeted catchment management interventions, we have, through the integration of data and modelling outputs, developed a programme of catchment investigations to diagnose possible causes for any degradation or failure to meet conservation targets within the SSSI/ SAC.

2.1.1. Pollution risk modelling

There are a variety of approaches available to model landuse and other human-derived pollution risks and estimate pollutant loads across each of the study catchments. These approaches include SCIMAP a fine sediment erosion risk model, SIMCAT and SAGIS to estimate the contribution of consented and un-consented sewage discharges, as well as inputs from diffuse sources, and PSYCHIC (Davison et al., 2008) to estimate phosphate and sediment loads delivered to receiving waters.

The outputs of these risk assessment tools and models have been combined with additional spatial data and evidence to identify potentially high risk areas for each pollutant in each catchment or sub-catchment.

2.1.2. Monitoring data review

Having assessed pollution risk a comprehensive review of historical and spatial evidence review encompassing data collated from the Environment Agency and where available variety of additional 3rd party sources. This review of the evidence will examine the observed / measured pollutant loads contributed by various sections of the catchment.

2.2. Intervention strategy development

2.2.1. Assessment of current mitigation measures in the catchment

Before a full catchment management plan can be developed it is necessary to have a clear understanding of what mitigation measures have already been put in place or are in the process of being implemented. We have therefore attempted to summarise the previous and on-going approaches adopted in the Camel catchment to mitigate the risks and impacts of pollution derived from a variety of sources. The measures assessed include the presence of naturally occurring mitigation in the landscape, the protection of the landscape through the designation of protected areas, the uptake of Environmental Stewardship Schemes (ESS), interventions delivered through Catchment Sensitive Farming and any other environmental work being done in the catchment.

2.2.2. Proposal for delivery of future intervention

FARMSCOPER modelling has been carried out to assess the potential achievable reductions for diffuse agricultural pollutant within the catchment. Mitigation method scenarios have been created using FARMSCOPER outputs, and informed methods lists have been detailed based on local knowledge. Based on all of our findings, we have, for the catchment, developed a detailed and costed intervention strategy, which we believe could remediate the problems found and mitigate the risk to the SAC/SSSI. These plans will outline which areas and activities represent the greatest pollution risk in the catchment and what interventions and resource allocation would be required to mitigate those risks. Furthermore, consideration has been given to future growth risk within the catchment, with estimates of the likelihood of resultant increases in pollution risk, and associated mitigation suggestions.

2.3. Assessment of potential outcomes

It is vital that sufficient evidence is collected to provide an objective and scientifically robust assessment of the effectiveness of our interventions. Ultimately, we must be able to justify any money spent and the interventions made across the landscape have delivered significant contributions to the delivery of conservation objectives and good ecological status of river catchments, along with secondary financial, ecological and social benefits.

3. Catchment overview

3.1. Morphology & hydrology

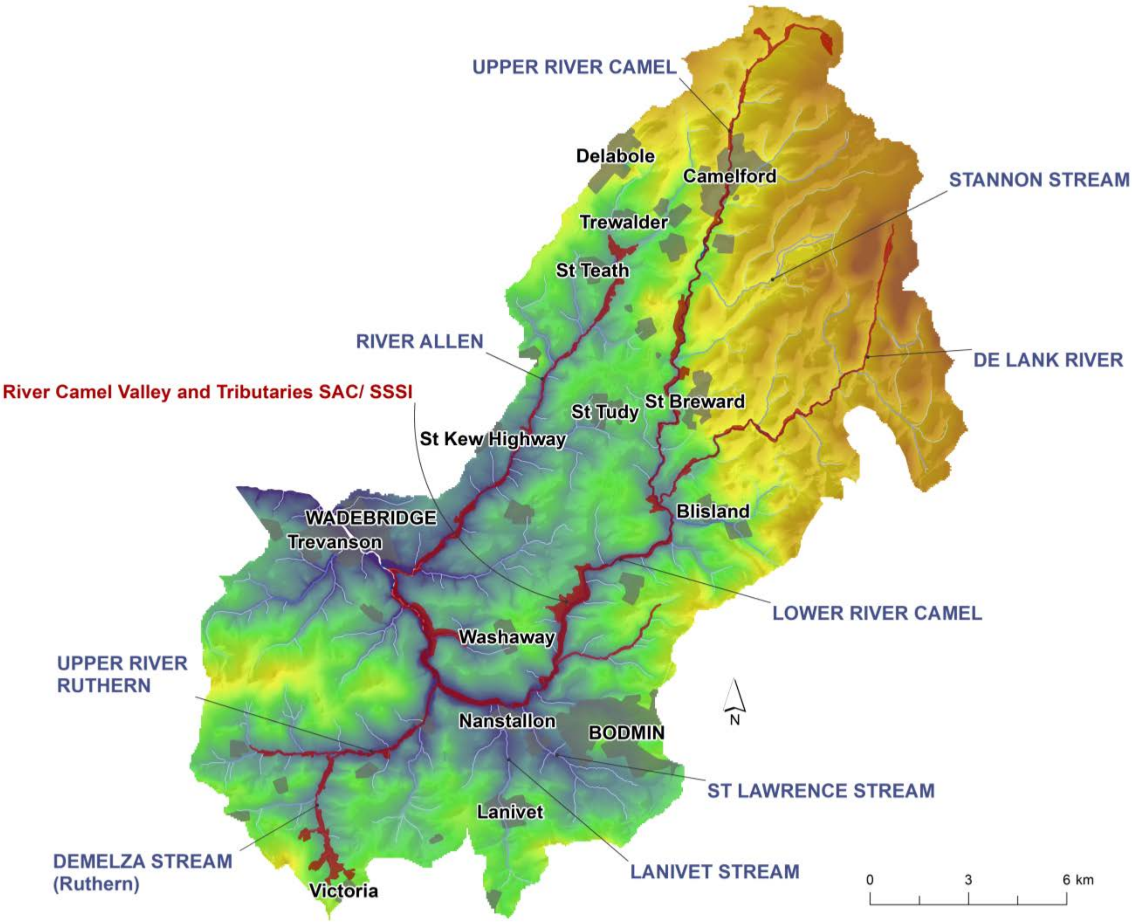
River Camel and its tributaries drain an area of around 314 km^2 in North Cornwall, South West England. The River Camel is around 84 km long, rising near the North Western edge of Bodmin Moor, National Park and flowing to Wadebridge, where the estuary connects with the Celtic Sea at Padstow Bay.

The River Allen is the main tributary of the River Camel. The River Allen joins the lower estuarine reaches of the main River Camel SAC/SSSI. The main tributaries in the upper reaches of the Camel are the Stannon Stream and De Lank River, flowing from the East. In the lower reaches of the catchment, significant tributaries include the Demelza Stream and the Upper River Ruthern which combine to flow into the River Camel near Nanstallon.

The headwaters of the River Camel flow from upland Granite bedrock of Bodmin Moor. The mid and lower reaches of the River Camel are underlain by low permeability Slates and Shales, with some Sandstone.

The River Allen has a similar geology to the River Camel, while the De Lank River flows through predominantly marshy alluvial flats on Bodmin Moor. The Upper River Ruthern and Demelza Stream are underlain by Slate and Shale geologies.

Figure 1: *Morphology of the Camel catchment showing key hydrological features and the location of the River Camel and Tributaries SAC/SSSI.*



The length of the Camel and its tributaries total approximately 324 km, and data from the Environment Agency's hydrometric gauging station at Denby near Bodmin reveal that the average daily discharge from the river is ~6 cumecs and that the flow exceeds this 30% of the time.

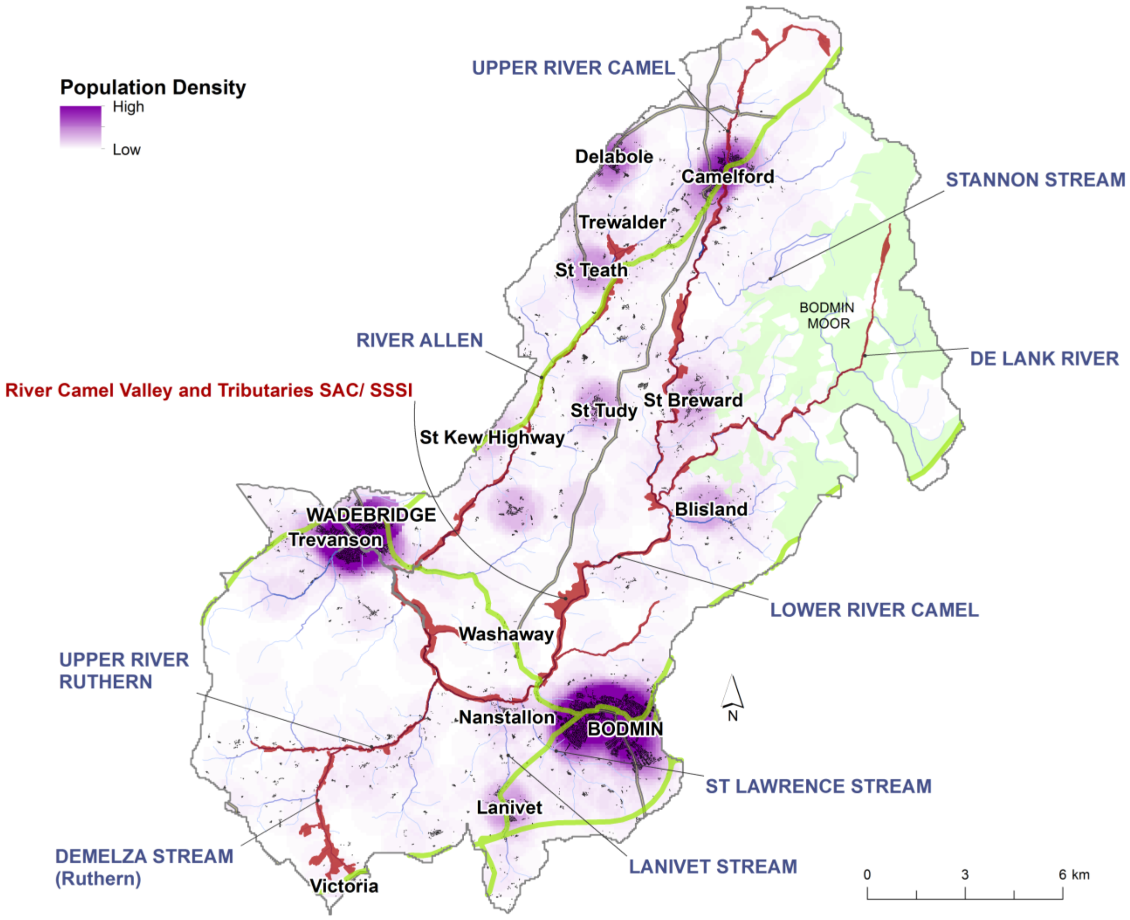
3.2. Social & economic

The Camel catchment has a population of approximately 21,000 (at an average density of 67/km^2) (see Figure 2). The two major towns in the West of the catchment are Bodmin (~15,000 residents) and Wadebridge (~7,000 residents).

There are a number of villages within the catchment, including Lanivet and Bisland, with around 3,000 residents in each. Major roads dissect the catchment including the A30 which runs along the Southern boundary of the Camel catchment, and the A39, which runs alongside the River Allen.

Social and economic data indicate that the economy of the catchment is particularly dominated by the retail, manufacturing and agricultural industries. Tourism also provides a major source of income within the Camel catchment.

Figure 2: *Population density and infrastructure in the Camel catchment.*



3.3. Farming & land-use

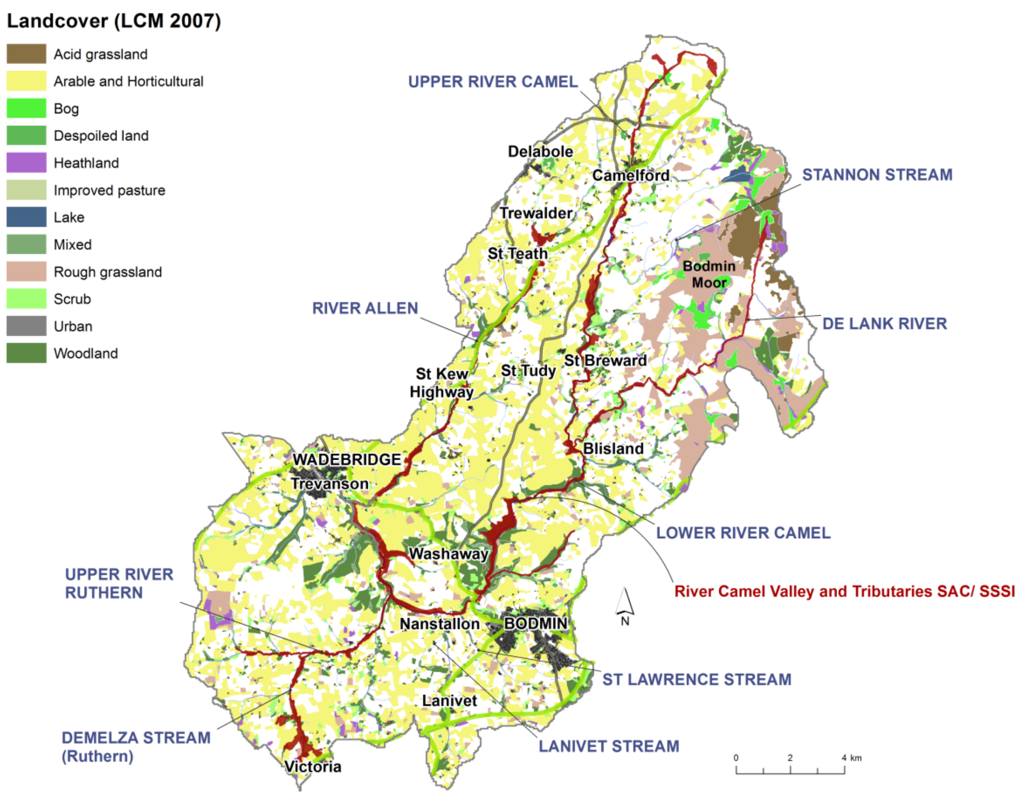
Data on agricultural practice and landuse derived from the Rural Land Register (2013) and the Agricultural Census of 2010 indicate that there are around 613 individual farm holdings in the catchment which cover around 26,200 Ha (~83 %) of the catchment area (Figure 4).

These farm holdings include fragmented patches of coniferous and broadleaf woodland and occasional scrub and heathland throughout the catchment (Figure 3).

Of the mapped farmland in the catchment; ~13,000 Ha (49 % of the farmed area) are under temporary or improved grassland and ~11,000 Ha (42 % of the farmed area) have been used to grow any form of crops. The remainder, which totals 2,800 Ha (10 % of the farmed area) in the catchment, is under rough/permanent pasture or woodland/forestry.

The total area of woodland/forestry in the catchment is ~2,227 Ha (7 % of the catchment area). Most of the woodland is concentrated around the Camel Valley. The North Eastern part of the catchment, which includes part of Bodmin Moor, contains a mixture of acid grassland, rough grassland and bog.

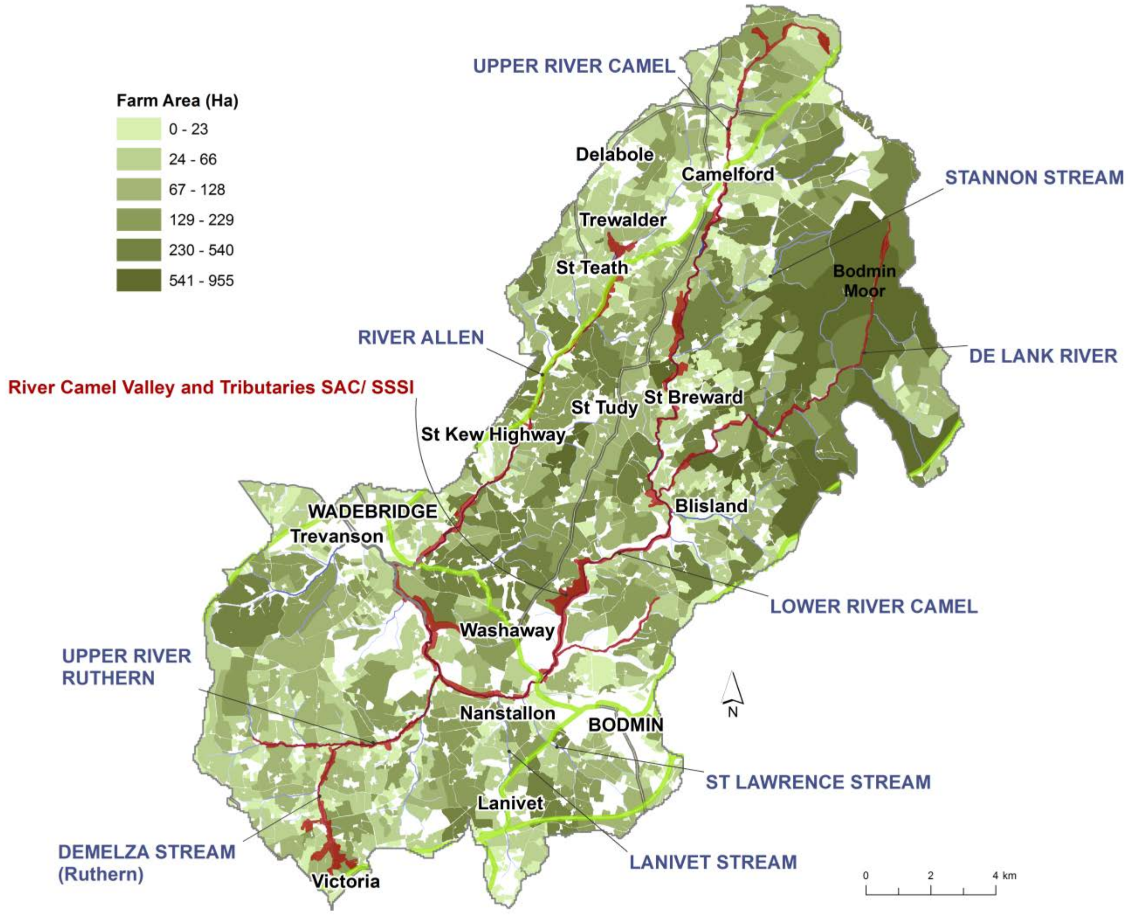
Figure 3: *Landuse data from Land Cover Map 2007 (CEH, 2010).*



The Rural Land Register data (Figure 4) indicates that ~207 of the farm holdings within the Camel catchment are over 30 Ha in size. Whilst only offering a coarse indication of numbers, as farm boundaries are rarely coincident with catchment boundaries, the 2010 Agricultural Census indicates that there are around 70 arable farms (predominantly maize and wheat) , 72 pig/poultry, 72 dairy and 72 beef farms in the catchment area.

It should be noted that the landcover 2007 map does not distinguish livestock and improved pasture, which are lumped together as 'arable and horticulture'. The Agricultural Census maps in Figure 5 show greater detail in agricultural landuse practices in 2000 and 2010.

Figure 4: *Farm boundary data from the Rural Land Register (2013) for the Camel catchment.*



A comparison between Agricultural Census data returns between 2000 and 2010 (Figure 5) clearly illustrate intensification across the catchment for all farm types (i.e. landcover and stocking rates).

The amount of land used for wheat farming increased by almost 4-fold, and for maize cropping decreased by 13 Ha between 2000 and 2010. Discrete areas of temporary grassland landuse were less intensive in 2010 comapred to 2000, but more widespread. In addition, a new area of temporary grasslands were recorded around Bodmin in 2010. Maize production decreased around Trevanson, with a new area occuring near St. Kew Highway in 2010.

Livestock numbers and stocking densities also increased, in particular, total sheep increase by ~40,000, and cattle numbers increased by ~24,000 between 2000 and 2010. Cattle farming became more intensive in all areas throughout the catchment, except Bodmin Moor. In contrast, sheep populations increased in and around Bodmin Moor and the southeastern corner of the catchment.

__Figure 5 (continues over page):__ Agricultural Census data from 2000 and 2010 showing the changes in the total area of land being cultivated for maize or temporary grassland and for the numbers of sheep and cattle in the Camel catchment.

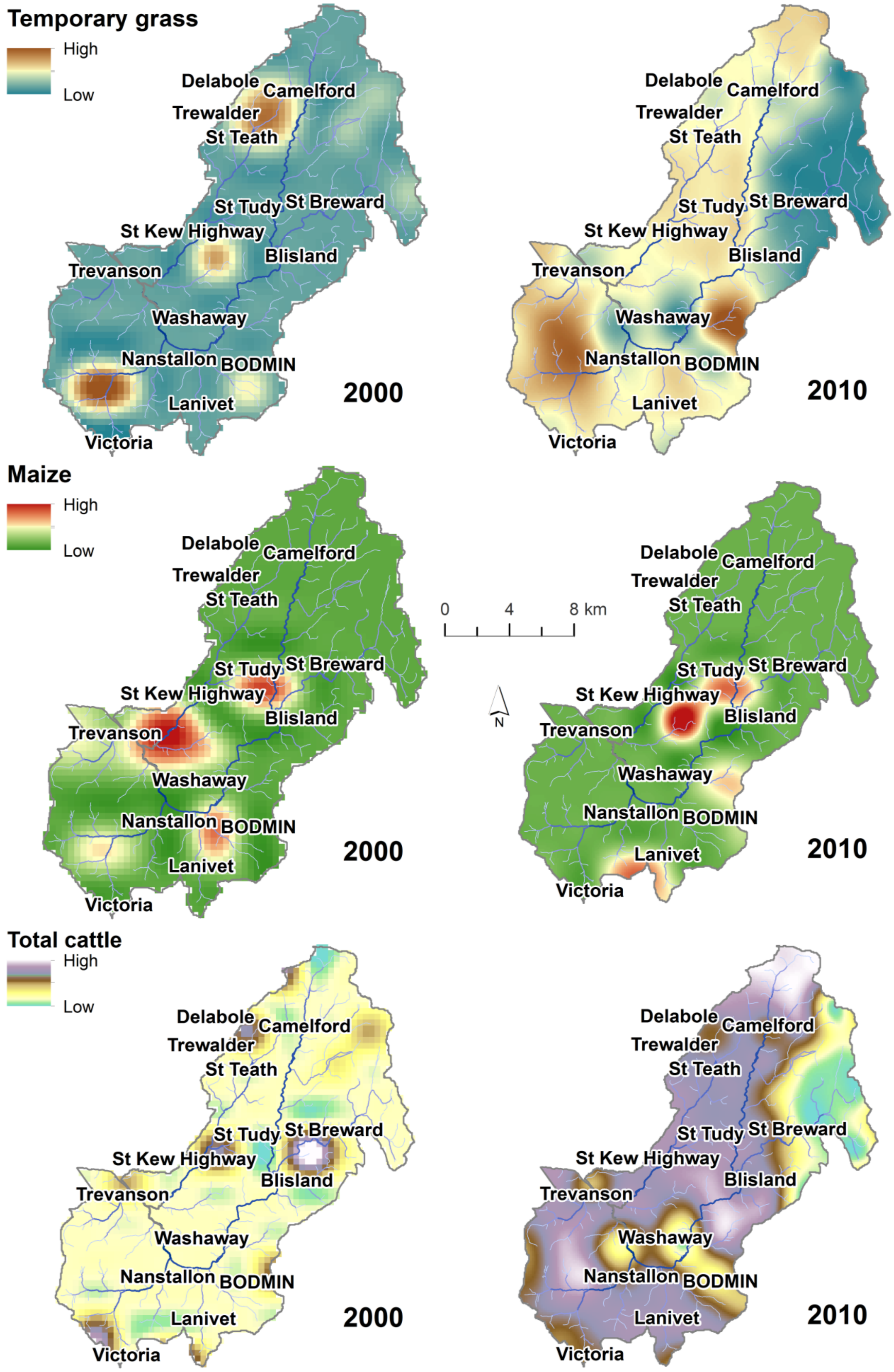
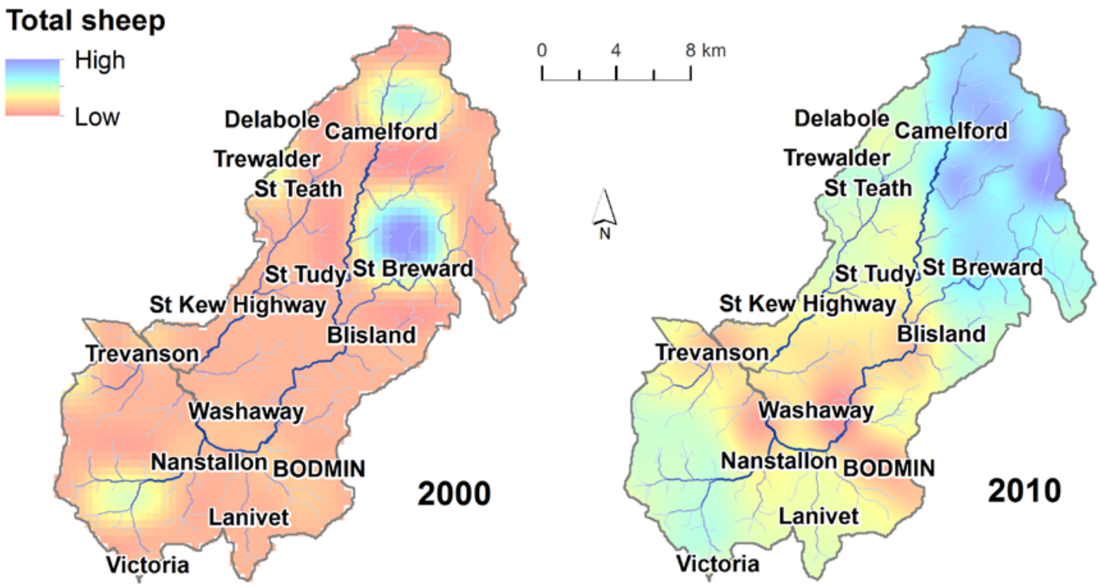


Figure 5 (….cont): *Agricultural Census data from 2000 and 2010 showing the changes in the total area of land being cultivated for maize or temporary grassland and for the numbers of sheep and cattle in the Camel catchment.*



4. Catchment classifications and challenges

Two status classifications relating to pressures on the River Camel and Tributaries SAC/SSSI are condition assessments for the SAC/SSSI itself, and WFD status of waterbodies within the catchment.

While Natural England are responsible for monitoring SAC/SSSI conditions, the Environment Agency carryout water quality monitoring for statutory and water management purposes. A brief description of SAC/SSSI and WFD assessment methods, standards and targets are provided below, followed by information on the current status of the River Camel SAC/SSSI and WFD waterbodies within the catchment.

4.1. River Camel SAC/SSSI status

In order to protect the species and biological integrity in the River Camel and Tributaries SAC/SSSI condition assessment targets must be met. The method for assessment of SAC/SSSIs includes methods and measures, such as, River Habitat Surveys (RHS), water quality assessment, and calculation of biological indexes.

Environment Agency monitoring data covering the three years preceding assessment are used to assess water quality and biological indices. The results of the assessment, in particular, status of the protected habitats and species, are used to define a condition for the site/ unit (JNNC, 2014).

The overarching condition of the River Camel and Tributaries SAC/SSSI is currently classified as 'unfavourable no change', meaning that *'The unit/feature is not being conserved and will not reach favourable condition unless there are changes to the site management or external pressures and this is reflected in the results of monitoring over time, with at least one of the mandatory attributes not meeting its target with the results not moving towards the desired state. The longer the SSSI unit* *remains in this poor condition, the more difficult it will be, in general, to achieve recovery. At least one of the designated feature(s) mandatory attributes and targets are not being met (JNCC, 2014)'.*

The main reasons for the adverse condition in the River Camel and Tributaries SAC/SSSI have been attributed to: water quality (levels of SRP and SSs); habitat structure (substrate and channel embankments; Salmon and bullhead numbers; and other in-stream attributes. In addition, the De Lank River fails for flow, due to abstraction pressures.

Two SSSI units covering 5 and 1.2 Ha, both near Bodmin, have been classified as 'unfavorable recovering' meaning that the *'units/features are not yet fully conserved but all the necessary management mechanisms are in place. At least one of the designated feature(s) mandatory attributes are not meeting their targets. Provided that the recovery work is sustained, the unit/feature will reach favourable condition in time'*. The 'recovering' condition has been attributed to a combination of river restoration strategy work and catchment sensitive farming (CSF) action.

We have carried out an assessment of the chemical status of the River Camel and Tributaries SAC/SSSI using Environment Agency monitoring data from 2010 – 2012.

Figure 6 below illustrates the chemical status of the SAC/SSSI across 7 locations. Table 1 details condition assessment targets compared with water quality concentration statistics for the River Camel and Tributaries SAC/SSSI.

It should be noted that the Common Standards Guidance (2014) no longer uses a specific numeric target concentration for suspended sediment (SS) to assess condition. In this report, a former condition assessment target of no more than 10 mg/ L as an annual mean for SSs in river and stream SAC/SSSI units, defined by Natural England, is used as a benchmark against which to compare measured water quality.

Figure 6: *Chemical condition assessment report card for the River Camel and Tributaries SAC/SSSI (data: 2010 – 2013). Sample site names are provided followed by EA water quality monitoring reference codes (in parentheses).*

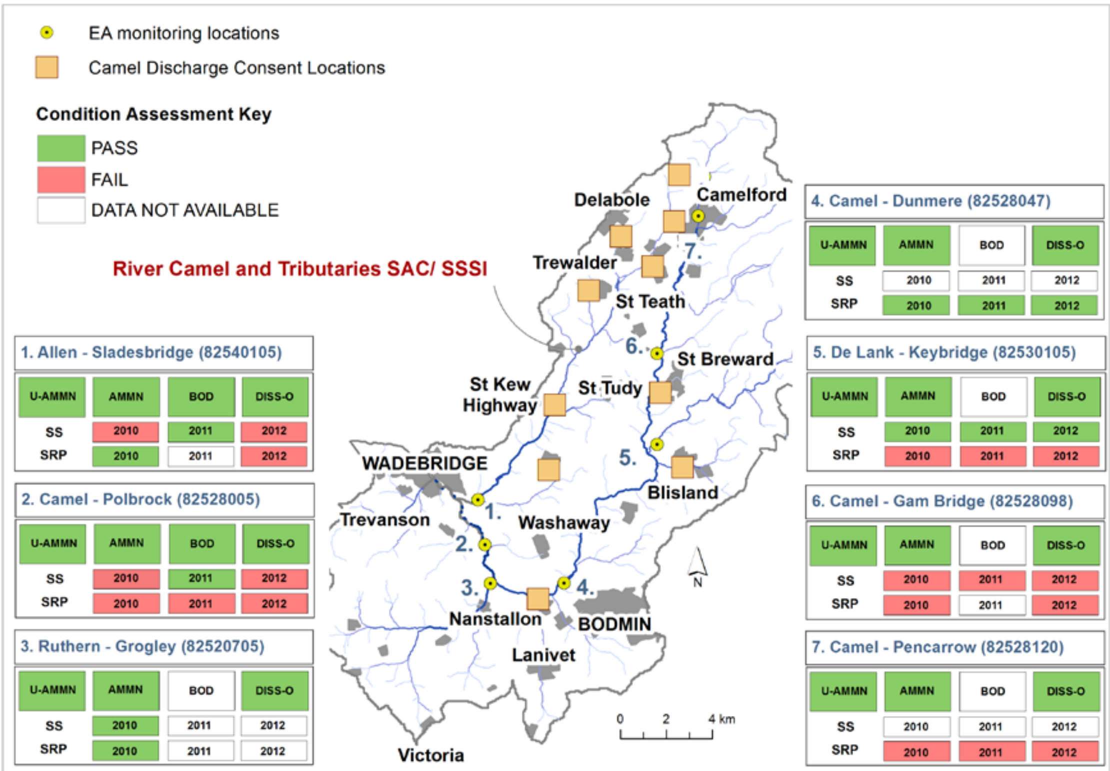


Table 1: *River Camel and Tributaries SAC/SSSI condition assessment target statistics compared with actual concentrations using EA monitoring data 2010 – 2012. Site number locations and names are shown in Figure 6.*

				Site number						
				1	2	3	4	5	6	7
Chemical parameter		**Statistic**	**Target**	**Actual**						
Un-ionised Ammonia (mg/l)		95^{th} %ile	0.025	0.0009	0.0007	0.0002	0.0006	0.0005	0.0005	0.001
Total Ammonia (mg/l)		90^{th} %ile	0.25	0.07	0.09	0.04	0.06	0.03	0.07	-
DO % Saturation		10^{th} %ile	>85	91.2	91.4	92.4	91.1	91.6	92.6	92
BOD (mg/l)		Mean	1.5	1.02	1.3	-	-	-	-	-
Suspended Solids (mg/l)	2010	Annual mean	10	15.2	11.4	4.8	-	4.7	18.8	-
	2011			9.9	6.1	-	-	4.5	10.8	-
	2012			13.9	25.3	-	-	6.3	18.1	-
SRP (mg/l)*			**SRP Target**	**0.03**	**0.04**	**0.02**	**0.04**	**0.013**	**0.02**	**0.01**
	2010	Annual mean		0.027	0.053	0.02	0.02	0.02	0.023	0.027
	2011			-	0.1	-	0.02	0.02	-	0.027
	2012			0.04	0.066	-	0.02	0.02	0.022	0.02

*variable site targets provided

Our condition assessment indicates that soluble reactive phosphorous (SRP) and suspended solids (SS) are the only water quality drivers for failure in the River Camel and Tributaries SAC/SSSI for the period 2010 - 2012. SRP concentrations were found to be above target near the tidal reaches of the River Camel at Polbrock (2010 – 2012).

2010 and 2012, SS concentrations in the River Camel Polbrock site were below the SAC/SSSI the 10 mg/l benchmark used in this report. In the River Allen at Sladesbridge (2010 and 2012) and Upper River Camel at Gam Bridge (2010 – 2012) the annual average SSs were 10 mg/l. SRP exceeded EQSs on average by 0.033 mg/l at Polbrock, with a maximum excedence of 0.06 mg/l in 2011. The maximum SS excedence was by 15.3 mg/l at Polbrock in 2012, the average excedence was 6.2 mg/l averaged across all failing sites and years.

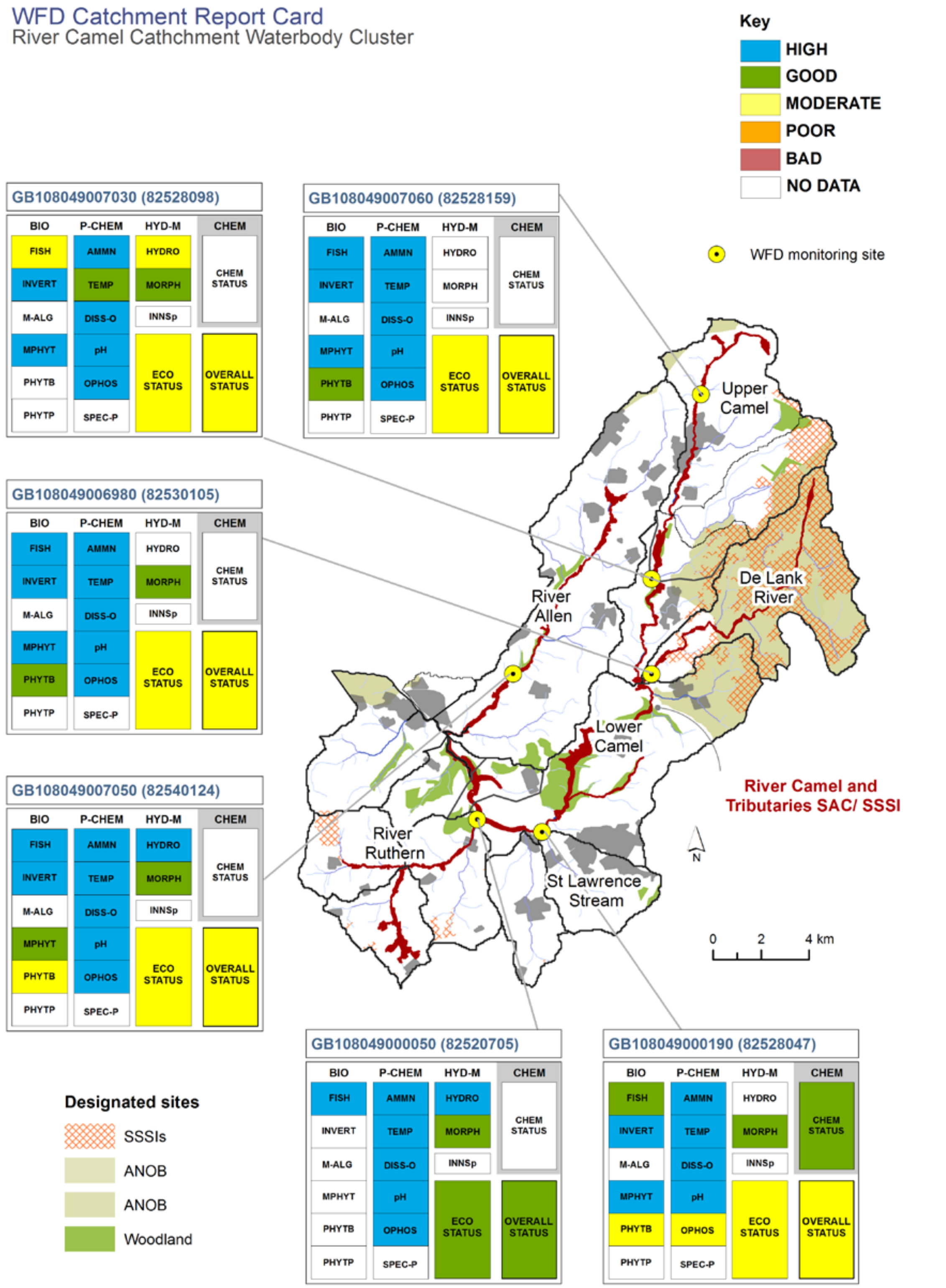
4.2. WFD classifications

The statuses and reasons for failure within Camel catchment WFD waterbodies, detailed in this section, provide information relating to physical, chemical and biological pressures in the Camel SAC/SSSI. It should be noted, however, that whilst WFD monitoring data and classifications can provide some insight into pollution issues, the low sampling resolution rarely allows for identification of high risk areas and provision of targeted interventions. For instance, many waterbodies only have one monitoring location, which may not always capture changes in water quality as pollution loads are added, diluted, sequestered and transformed via natural processes as they are transported downstream.

It should be noted that the WFD EQS for phosphate classification may be updated in 2014 as part of the review of WFD classification being undertaken for the 2nd Cycle of River Basin Management Planning by the Environment Agency.

These proposed changes, recently set out in a provisional report, will see the phosphate standard standards defined by river type in a manner similar to the current SAC/ SSSI standards for tha Camel catchment.

Figure 7: Water Framework Directive 'Health Card' for the Camel catchment, 2013 (data source: EA, 2013).



Both SAC/SSSI condition assessments and WFD classifications do not have a target measure for SS in their assessment. Due to more strigent SAC/ SSSI EQSs for SRP (or OPHOS), SRP has not been highlighted as a problem in areas where it has failed targets under the SAC/ SSSI assessment. For instance, under WFD, SRP is classed as only moderate for the Lower Camel, and is thus not highlighted as a problem.

In Figure 7, most sites have been classified as 'good' or 'high' for SRP, except for the Lower River Camel which was 'moderate' for WFD and failing for SAC/SSSI EQSs. Sites in the south of the catchment (Lanivet Stream, St Lawrence Stream, Polmorla Stream, Lower and Upper River Ruthern) had 'good' ecological and overall status. All rivers in the mid and upper reaches of the catchment (River Camel, River Allen, De Lank River and Stannon Stream) were classified as having 'moderate' ecological and overall status.

5. Pollutant source identification & risk assessment

Having assessed WFD and SAC/SSSI classifications, along with issues highlighted in existing literature it is clear that SRP and SS, pose the greatest water quality risk to specific areas of the River Camel SAC/SSSI.

In this section we present an integrated assessment of both observed and derived (modelled data) to identify potential sources of SRP and SSs in the Camel catchment, and their relative contribution to the in river-concentrations / loads within the SAC/SSSI. This desk-based assessment is undertaken in accordance with the 'source-pathway-receptor' principle of pollution. The focus of this assessment was on the pollutants listed in Table 2).

SOURCE | PATHWAY | RECEPTOR

Pollutant Availability + Mobilisation + Connectivity = Pollution risk

5.1. Suspended solids

Numerous methods have been developed to identify the sources of SSs and the dynamics of sediment transport in rivers. Overall these studies reveal that the sediment load in rivers is primarily derived from point or diffuse sources in three principal locations: material from the river channel and banks, soil and other organic material from the surface of surrounding land and particulate material from anthropogenic sources (e.g. roads, industry and urban areas).

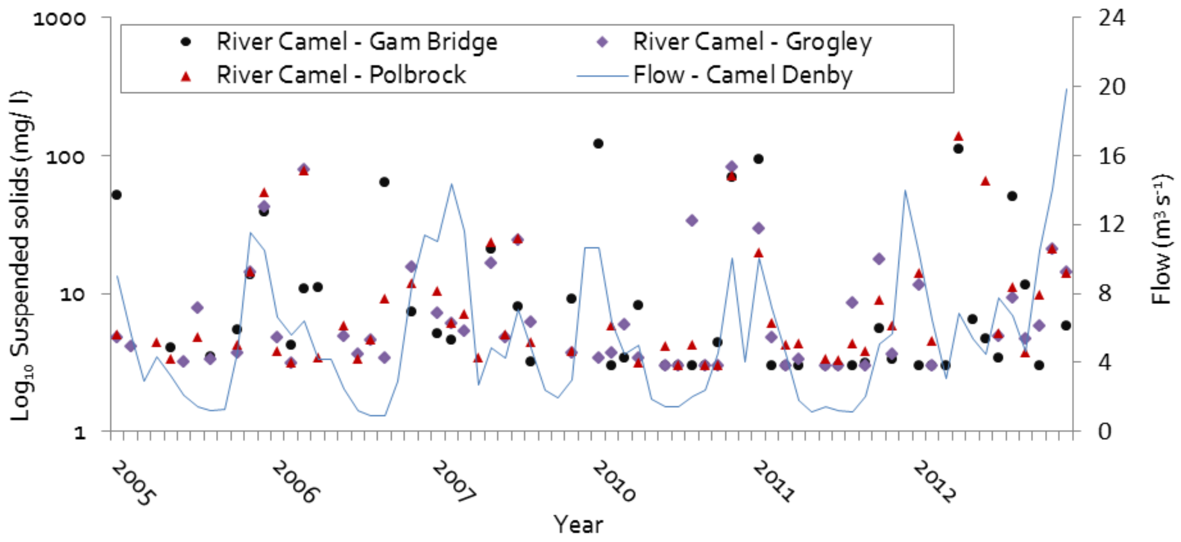
In the following sections, we present water quality monitoring data, SCIMAP risk modelling, sediment fingerprinting data and walk-over data to attempt to quantify, identify areas of high risk and apportion sediment pollution in the Camel catchment.

5.1.1. Water quality assessment

Statutory monitoring data and past research indicate that elevated SS concentrations within the Camel catchment are likely to be a water quality risk for the Camel SAC/SSSI. WFD monitoring data from 14 sites, within the Camel catchment indicate that, between 2010 and 2012, SS concentrations exceed the annual condition assessment targets 50% of the time, with these elevated concentrations ranging from 10.8 to 25.3 mg/ L.

Figure 8 shows monthly averaged Environment Agency SS data, at sites which had long-term data sets. The flow hydrograph shows monthly averaged flow data (CEH, 2014) from the River Camel – Denby flow gauging station (NGR: SX0174868159). Significant correlations were not found between flow and SS; and there was no clear temporal trend in the SS data. Variability in SS pollution levels are controlled by a range of factors including rainfall, soil characteristics, riparian vegetation and landuse practices.

Figure 8: *Graph showing monthly averaged long-term flow data for the River Camel at Denby (CEH, 2014) and suspended solid data for the River Camel at Gam Bridge, Polbrock and Grogley (EA, 2014) for Jan 2005 – Dec 2012.*



It may be useful to assess relationships between changes in landuse practices and SS concentrations within the Camel catchment. However, low sampling resolutions for SS mean that it is difficult to identify, specifically diffuse, pollutant sources with monitoring data. Sediment fingerprinting studies can be used to identify and apportion sources of sediment pollution.

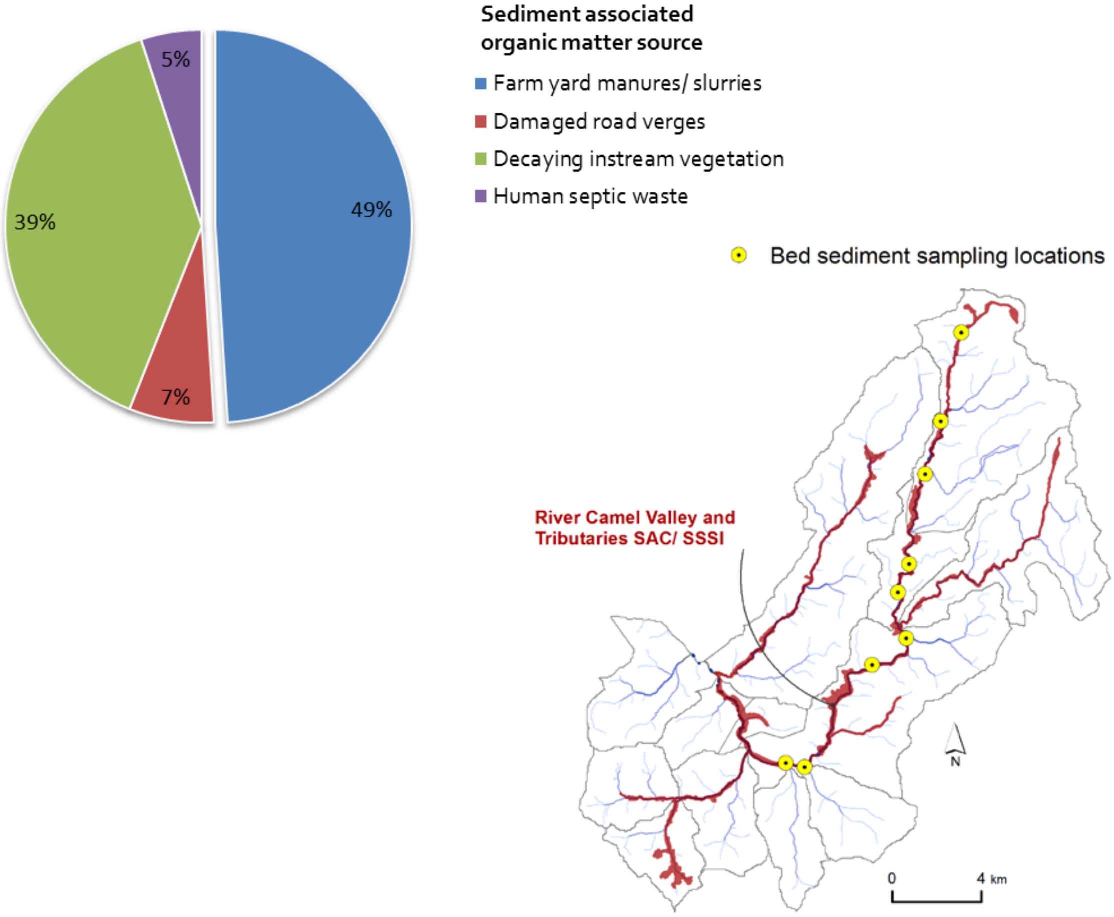
5.1.2. Sediment source apportionment

The chemical composition of sediment samples can be analysed to identify their sources. In 2013, ADAS carried out a reconnaissance study of sediment-associated organic matter sources, sediment oxygen demand and phosphate sources in the River Camel. The reconnaissance study included an initial analysis of sediment associate organic matter sources taken from 8 river-bed sites in the Camel catchment. Figure 9 shows the relative frequency-weighted average median contributions from the individual source types, which were aggregated from 9 river bed sediment sample sites (Figure 9 inset).

The results of the 2013 ADAS study indicate that farm yard manures/ slurries (49%) were the greatest source of sediment associated organic matter across sampling sites in the Camel catchment. Relatively large numbers of dairy farms across the catchment, as shown by Agricultural Census data support this finding. This indicates that sediment pollution is likely to be derived from dairy farms within the Camel catchment. Decaying instream vegetation supplied 39% of the sediment associated organic matter. However, this is not an important consideration in this report as we are trying to identify sources of sediment pollution which result from human activity within the catchment. The results also found that damaged road verges and human septic waste were sources of sediment associated organic matter, but were not significant sources.

P pollution is associated with organic matter from farm yard manures/ slurries and human septic waste and is assessed in section 5.2.

Figure 9: *Sediment associated organic matter source apportionment (Data source: ADAS, 2009). Bed sediment smapling site location map inset.*



While the sediment associated organic matter study can provide some indication of sediment sources within the Camel catchment, it should be noted that this study was a reconnaissance and a higher sampling resolution, both temporal and spatial, would be needed to inform a more robust assessment.

Sources of elevated suspended solids within the River Camel and tributaries will be originating from either or both diffuse and point sources, being mobilised and transferred from a number of sources across the catchment. We have undertaken a risk assessment to identify the areas with an elevated risk of fine sediment erosion.

5.1.3. Fine sediment risk analysis

In addition to the mobilisation of sediment and other suspended material from within the riparian corridor, fine sediment can also be mobilised from land-surface sources by overland flow. We can identify potential sources of this kind through field surveys, but to get an initial catchment wide assessment of the risk we can use a spatial modelling approach to assess the fine sediment erosion and mobilisation risk across the Camel catchment.

A catchment scale assessment of erosion risk is beneficial in helping to target and tailor both further monitoring, advice and catchment management interventions.

The SCIMAP fine sediment risk model, developed through a collaborative project between Durham and Lancaster Universities (Reaney, 2006) was used for this purpose. The development of this risk modelling framework was also supported by the UK Natural Environment Research Council, the Eden Rivers Trust, the Department of the Environment, Food and Rural Affairs and the Environment Agency.

SCIMAP provides an indication of where the highest risk of sediment erosion risk occurs in the catchment and the in-channel risk by (1) identifying locations where, due to land-use, sediment is available for mobilisation (pollutant source mapping) and (2) combining this information with a map of hydrological connectivity (likelihood of fine sediment, and associated pollutants mobilisation and transfer).

The SCIMAP risk modelling framework produces a map of hydrological connectivity based on the analysis of the potential pattern of soil moisture and saturation across a landscape. For each point in the landscape, the probability of continuous flow to the river channel network is assessed. This is achieved through the spatial prediction of soil moisture and hence the susceptibly of each point in the landscape to generate saturation excess overland flow.

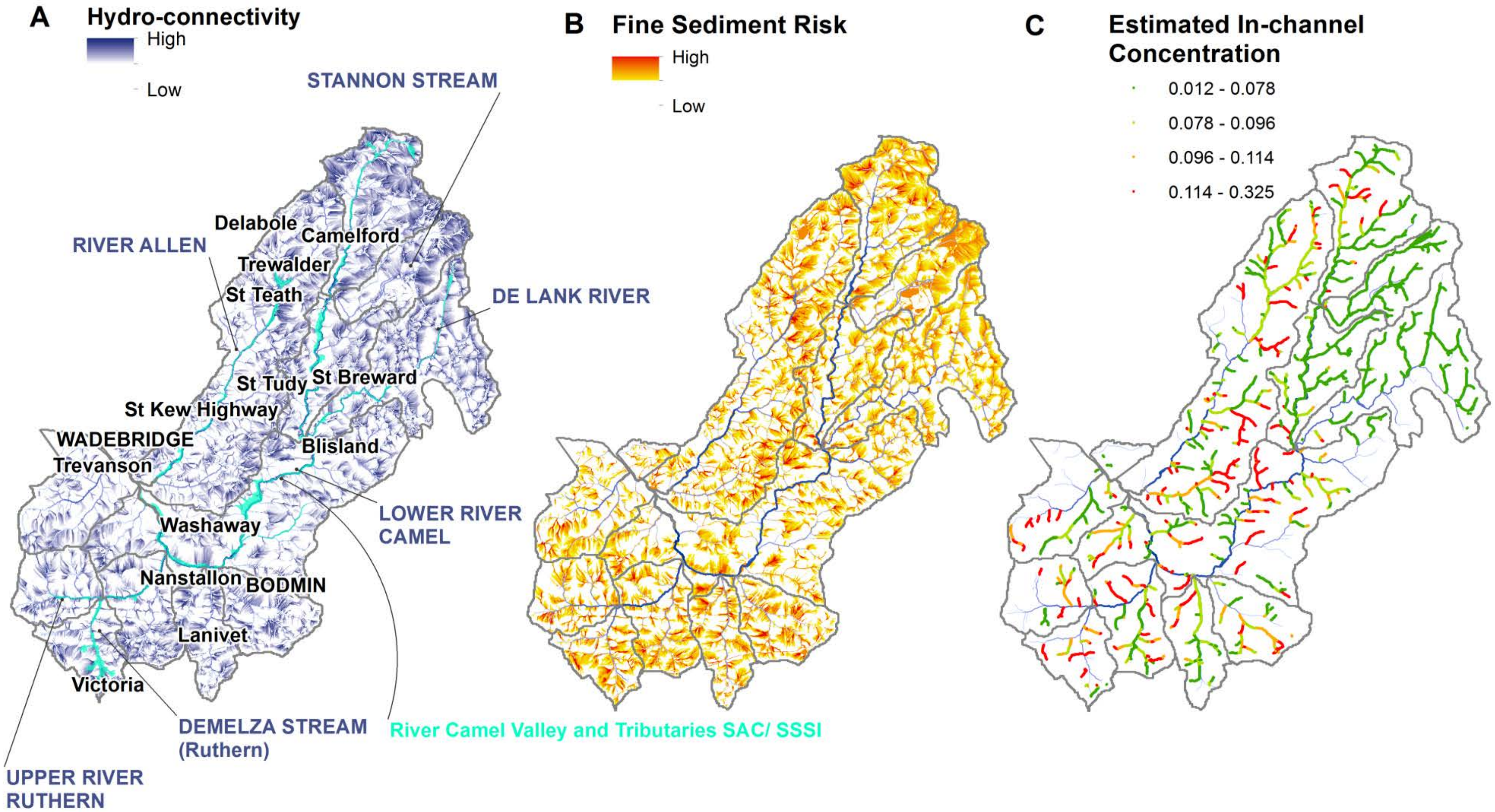
In the report, the Camel catchment has been analysed strategically at 10, 5 and 2m resolutions. The 5m resolution has been split into three representative sub-catchments, to allow SCIMAP analysis to be carried out with higher resolution data. As the SCIMAP outputs are relative, each sub-catchment has been analysed independently. The hydrological connectivity map resulting from this analysis is shown in Figure 10 A, whilst the resulting fine sediment erosion risk and estimated in-channel concentration maps created from this analysis are shown in Figure 10 B and C respectively.

The output from SCIMAP in Figure 9 clearly shows that there are a number of small streams which may act as pathways for fine sediment mobilisation in the Camel catchment. Most of the fine sediment run-off risk is concentrated in the southern reaches of the catchment.

These are areas of land where cultivation or improvement of grassland and/or the action of livestock may increase the availability of sediment for erosion. There are a number of areas where there is an elevated likelihood of run-off occurring during periods of high rainfall.

The areas with greatest risk of in-channel sediment are where landuse practices contribute to sediment erosion and where there is high connectivity to watercourses. These are concentrated in the sub-catchments of the River Allen, River Ruthern and Lower River Camel and a number of small streams which flow directly into the River Camel and Tributaries SAC/SSSI.

Figure 10: *Fine sediment erosion risk maps of the Camel catchment, derived using the SCIMAP modelling approach, 10m DEM resolution.* ***(A)*** *Surface Flow Index model derived from rainfall and topographic data in the SCIMAP modelling framework,* ***(B)*** *Fine sediment erosion risk model, and* ***(C)*** *Estimated in-channel sediment concentration model.*



SCIMAP modelling indicates that fine sediment in-channel risk risk occurs specifically in the lower reaches of the Camel catchment. In combining the areas with highest fine sediment erosion risk and the estimated in-channel concentration, discrete high risk areas can be identified (Figure 12). Figure 14 also provides an example of the SCIMAP analysis at 5m resolution.

The high resolution SCIMAP analysis in Figure 13 clearly shows that there are a number of areas with high sediment erosion risk which have high connectivity with river channels in the Camel catchment. Furthermore, 2007 CEH landcover data indicates that high risk sediment erosion areas often occur on arable land, which can be a source of diffuse agricultural sediment pollution.

These high risk areas could be significant sources of sediment pollution to receiving waterbodies, where agricultural 'Best Management Practices' BMP's are not applied.

In addition, agricultural land with high sediment erosion risk is also likely to be a source of P to receiving waters as P is often physically and chemically bound to sediment. P pollution in the Camel catchment is explored in section 5.2.

Figure 12: *Fine sediment risk and estimated in-channel concentration modelled at 10m resolution in SCIMAP. Areas with risk > 70% fine sediment risk are shown. Selected areas have been modelled at 2m resolution Figure 13.*

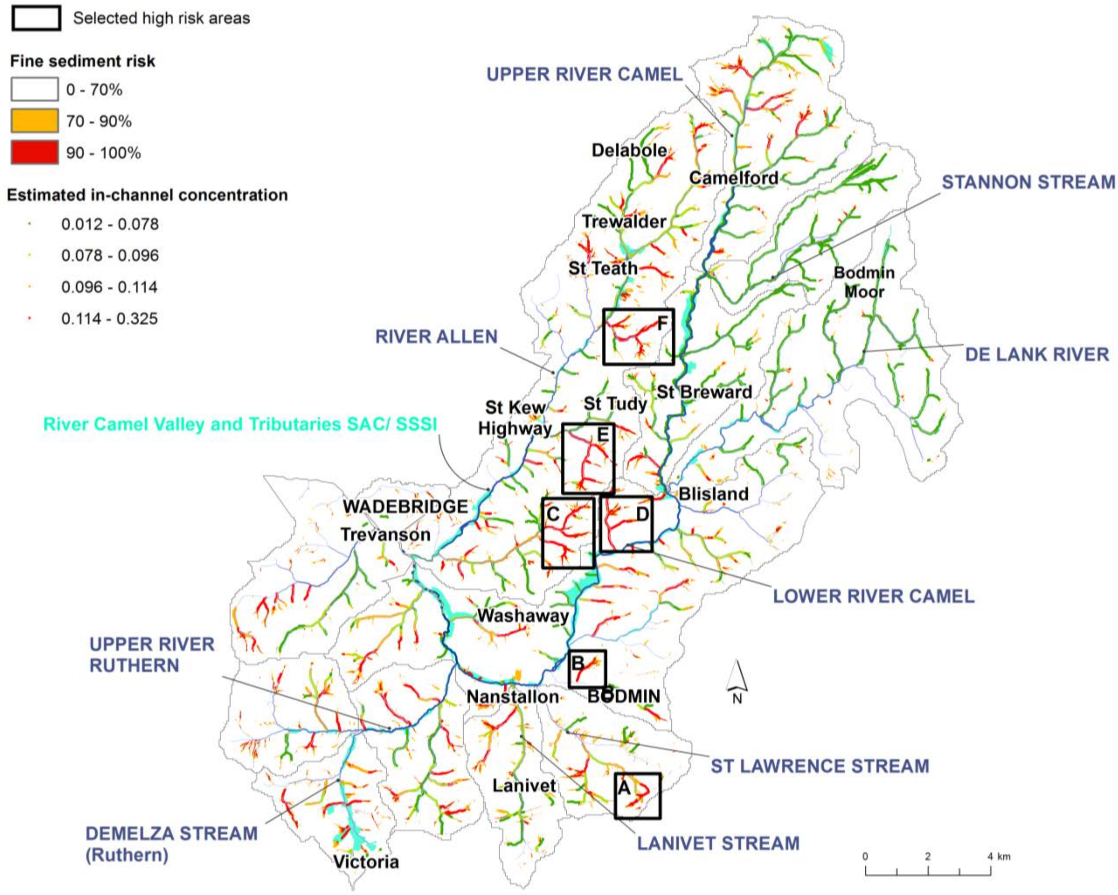


Figure 13: *SCIMAP fine sediment risk maps modelled at 2m resolution for areas identified as having high fine sediment erodability risk at 10m resolution.*

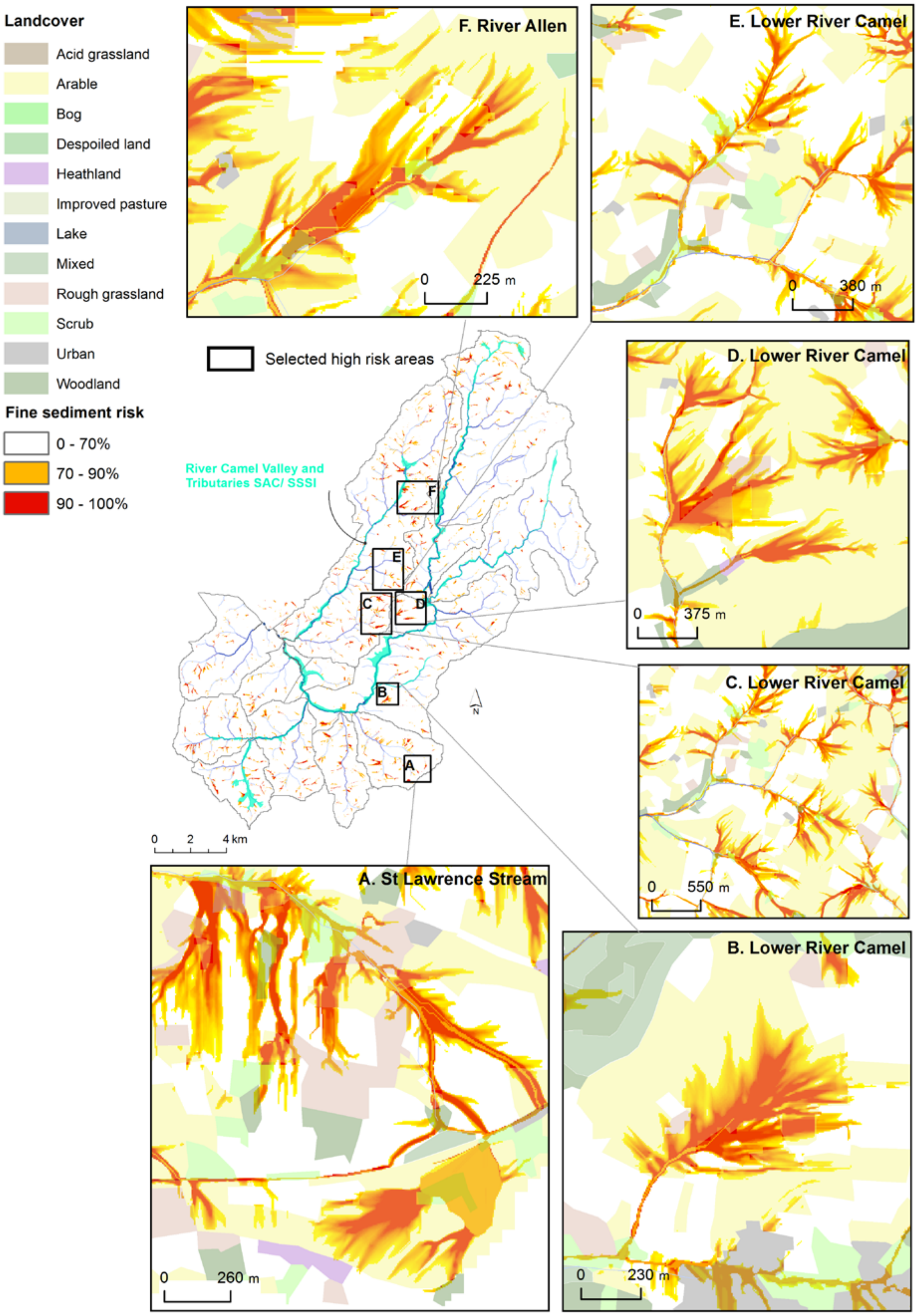
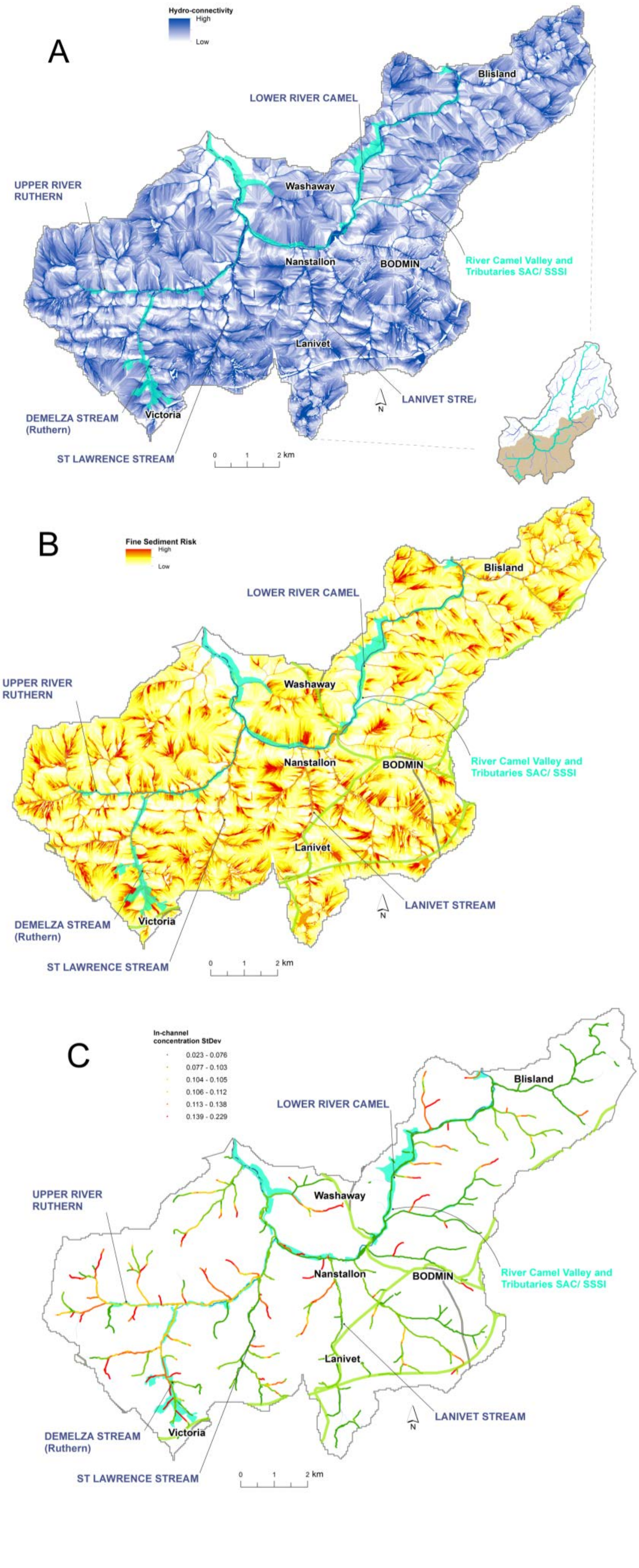


Figure 14: *Example fine sediment erosion risk maps of a Camel sub-catchment, derived using the SCIMAP modelling approach, 5m DEM resolution.* ***(A)*** *Surface Flow Index model derived from rainfall and topographic data in the SCIMAP modelling framework* ***(B)*** *Fine sediment erosion risk model.* ***(C)*** *Estimated in-channel sediment concentration model.*



5.1.3. Sediment load analysis

Having identified where the greatest fine sediment erosion risk may be present in the Camel catchment, we next interrogated the water quality monitoring data collected at strategic locations in the catchment to identify which areas were contributing the greatest amount of suspended solids. **For this study we examined 3 years of Environment Agency water quality monitoring data at 5 key locations across the catchment (shown in Figure 15; locations *inset*).**

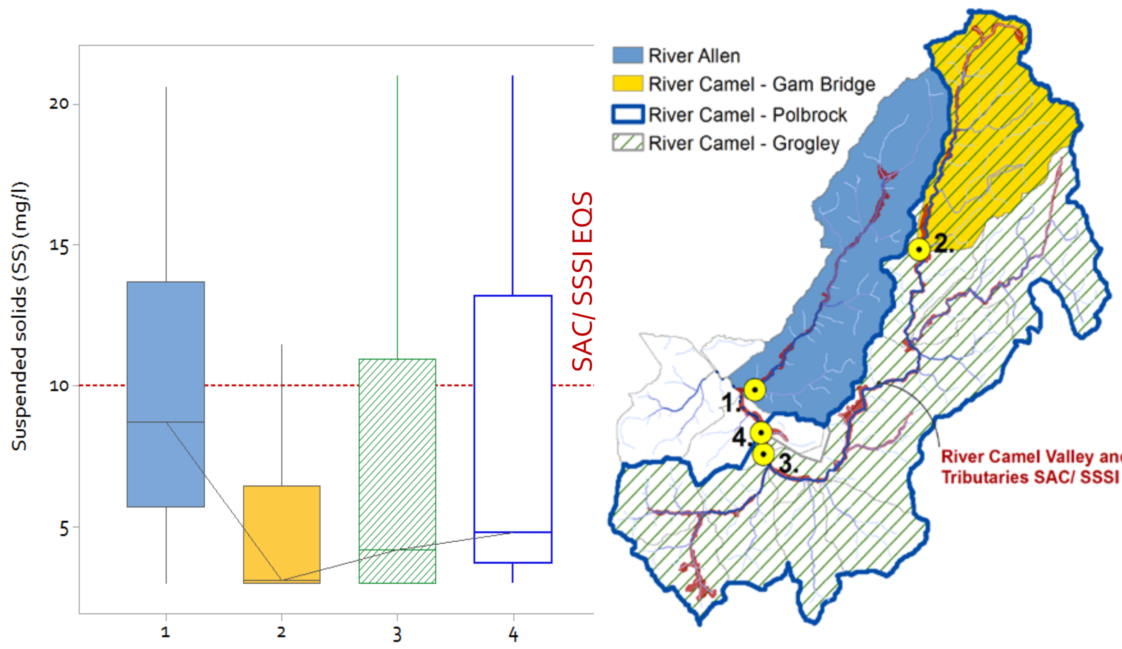
Figure 15 shows the average suspended solids concentrations recorded by the Environment Agency over a 3 year period between 2010 and 2012. Samples were taken at the outflow of the River Allen and at 3 locations along the main River Camel with a monthly sampling frequency. There were no suspended solids data available in the other sub-catchments.

Suspended solid data indicates that there was a higher average suspended solid concentration in the River Allen compared to any of the sites in the River Camel. The average suspended solid concentrations and ranges for the River Camel increased downstream, indicating additional loads of suspended solids from larger sub-catchments. The increased sediment load between site 3 (Camel – Grogley) and 4 (Camel – Polbrock) may be originating from the small drainage area between the two sites, or from in-channel erosion. However, due to the distance between the two sites and river corridor characteristics, the former is more likely.

Due to large diffuse pollution source areas and low resolution in the water quality data for, it is difficult to identify specific sources of suspended solids in the Camel catchment. These data do, however, indicate that, as identified in the SCIMAP modelling, areas around the River Allen and mid-reaches of the Camel catchment may be significant sediment sources.

The high sediment risk areas, which have a short pathway between the source and receptor, in Figure 13, show likely source areas of sediment pollution in the River Allen and River Camel. The highest suspended sediment (~ >15 mg/l) levels are likely to occur during spate conditions when large amounts of sediment are washed down thorough the catchment.

Figure 15: *Variation in suspended sediment concentration in 5 locations in the Camel catchment (locations; inset).*



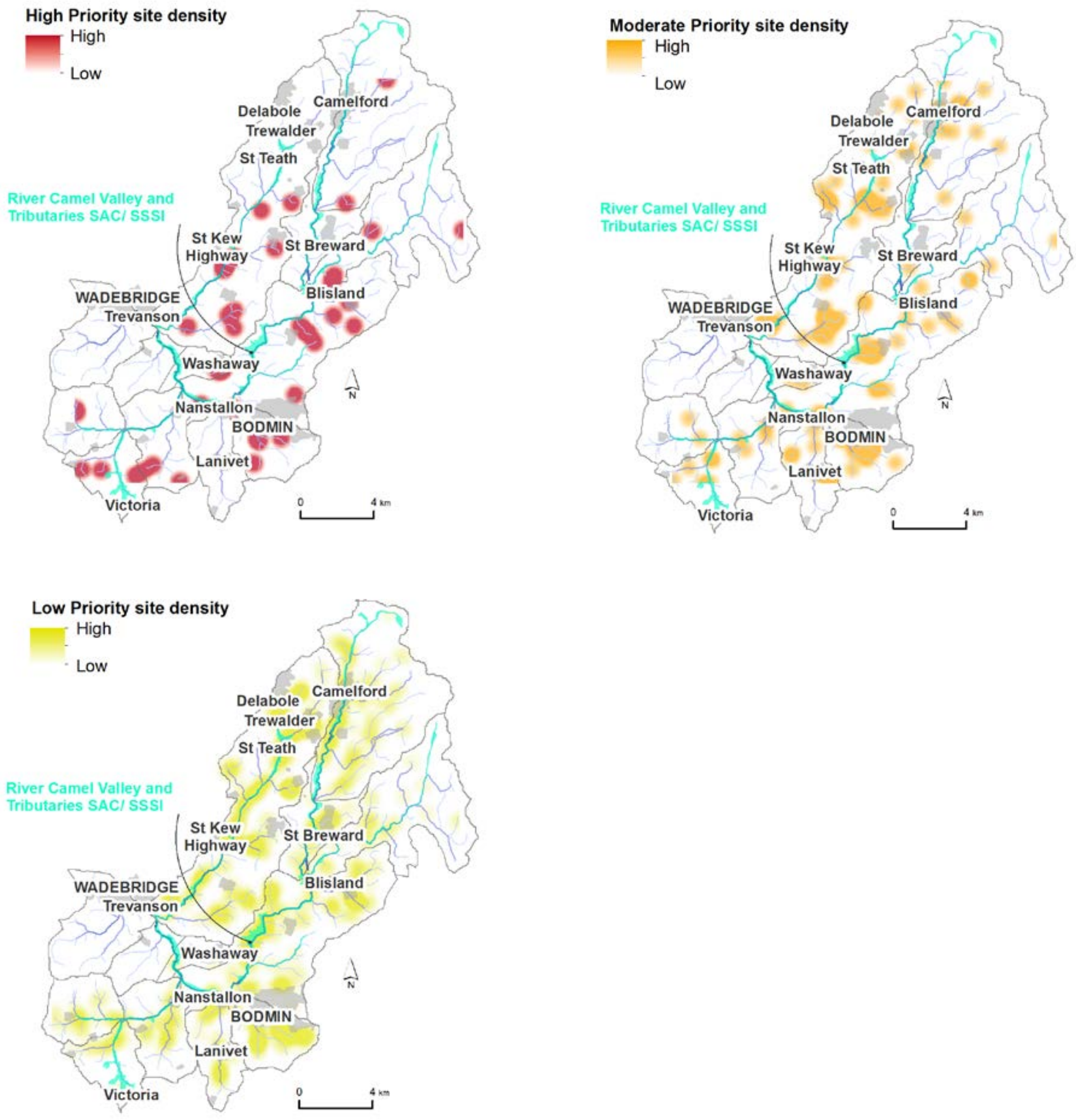
5.1.4. River corridor & landscape sediment risk assessments

Fine sediment or suspended solids pollution in rivers can be derived from natural geomorphological processes, such as bank and channel erosion, and through erosion of the soil and materials from the land surface during run-off events.

These inputs can be significantly increased if river banks and channels become damaged or excessively disturbed due to the actions of livestock given unrestricted access to the watercourse or if soil condition is degraded due to the farming practices being undertaken upon it.

Walkover surveys can provide detailed fine scale information about sediment source areas. The Environment Agency commissioned walkover survey of the Camel catchment undertaken in 2014 (figure 15a).

Figure 15a: *Density of high risk sediment run-off areas, identified via walkover surveys (EA, 2014).*



5.2. Nutrients

For the purposes of this study we have focused our modelling and assessment of nutrients on phosphorus (P) containing compounds, which are having a deleterious impact on the status of the SAC/SSSI.

There are two principal measures of phosphorus soluble reactive phosphate (SRP) and total phosphorus (TP). The soluble reactive form is regarded as being biologically available and is the limiting nutrient that facilitates the growth of algae. The insoluble fraction of total phosphorus is often associated with suspended solids in the water and is often ignored, but it can rapidly become biologically active through decomposition or solubilisation and there are many who believe that total phosphorus is the better or more complete measure of phosphorus load in rivers.

There are three principal sources of phosphorus compounds in a river catchment: (1) point agricultural sources, (2) diffuse agricultural sources and (3) point anthropogenic sources. The potential for these sources to generate nutrient pollution in the Camel catchment are described in the following sections.

5.2.1. Water quality analysis

Within the River Camel and Tributaries SAC/SSSI, phosphorous can have an impact on water quality and biological integrity via enhancement of algal and plant growth. Excess phosphorus can have a significant impact on the general ecological health of the aquatic ecosystem of the river (especially at a localised scale).

Water quality monitoring data obtained from the Environment Agency indicate that the SRP concentrations exceed the annual average current WFD Environmental Quality Standard (EQS) of 0.12 mg/L as well as the tighter standards set within the Camel River and Tributaries SAC/SSSI itself in the River Camel at Polbrock.

Long-term Environment Agency monitoring data is used to identify trends in SRP concentrations (Figure 17). Annual SRP averages have generally been decreasing since 2005. Despite this decrease SRPconcentrations are still above SAC/SSSI EQSs in the River Camel at Polbrock. The "step-change" decreases observed in annual SRP concentrations are likely to be due to phosphorus stripping which was implemented at Camelford, and Scarletts Well sewage treatment works in 2008.

Figure 16: *Locations of Environment Agency SRP monitoring sites analysed in Figure 17.*

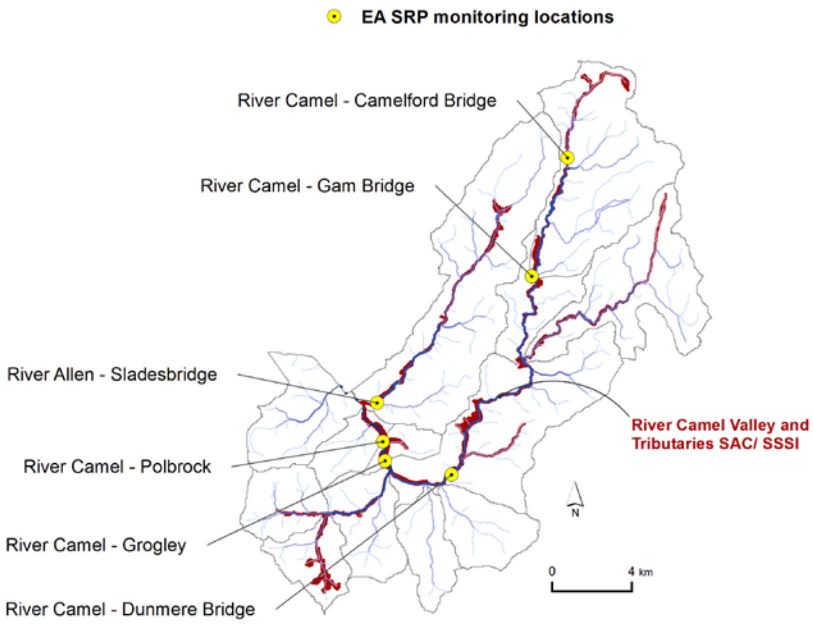
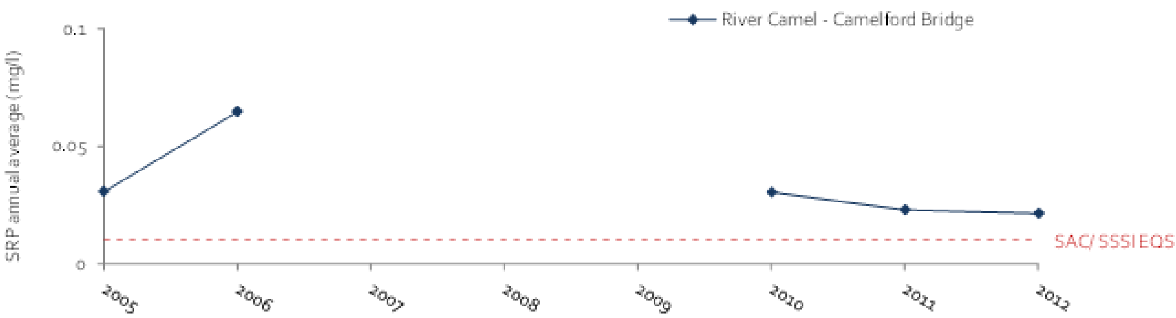


Figure 17: cont. over page… *Long-term SRP annual average trends in relation to WFD and SAC/SSSI Environmental Quality Standards (EQS) in the Camel catchment.*



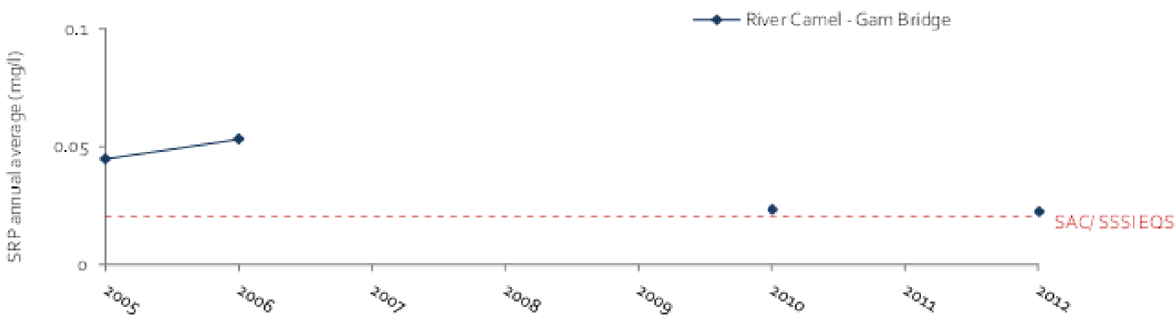


Figure 17: …cont. *Long-term SRP annual average trends in relation to WFD and SAC/SSSI Environmental Quality Standards (EQS) in the Camel catchment.*

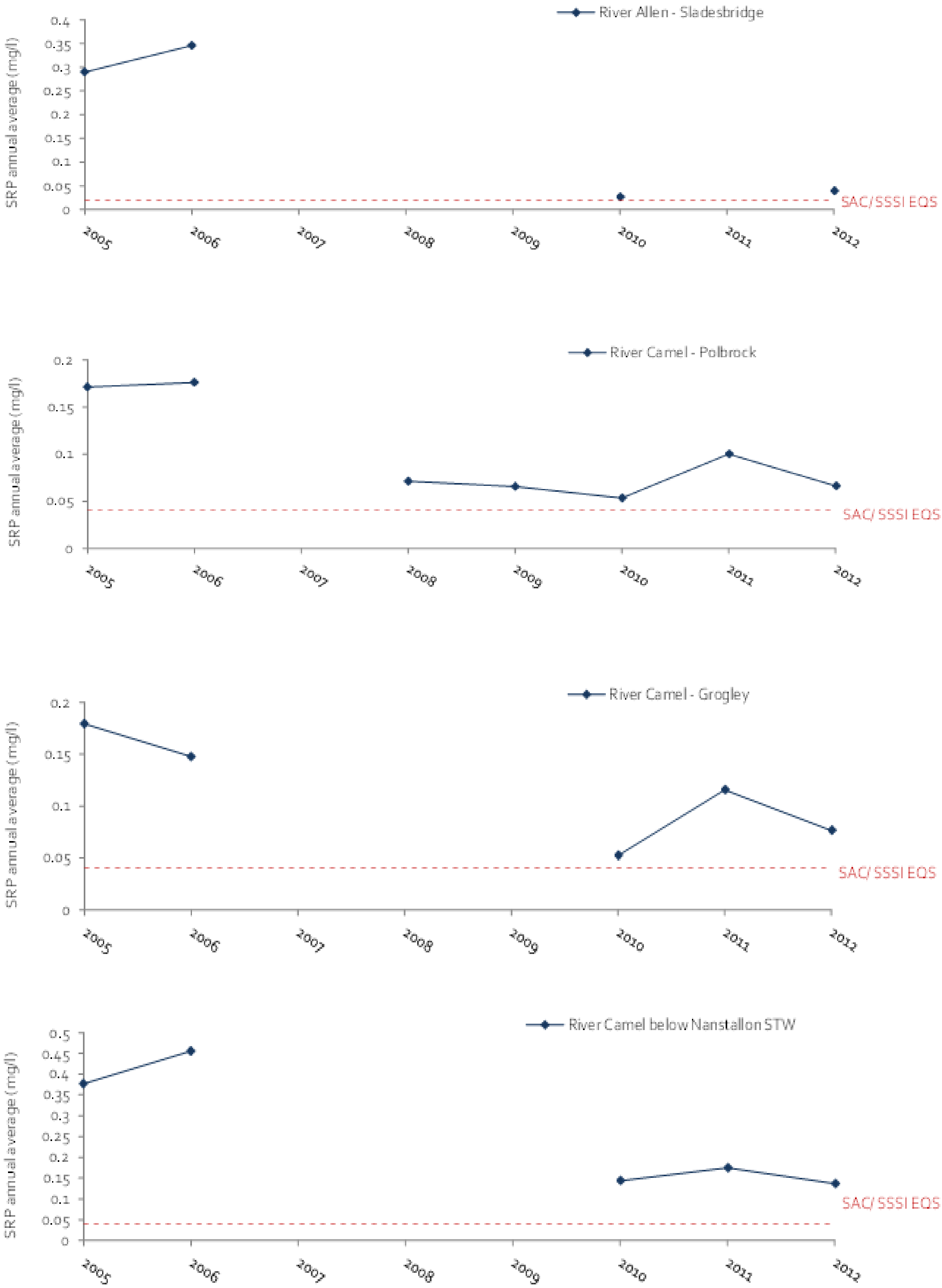
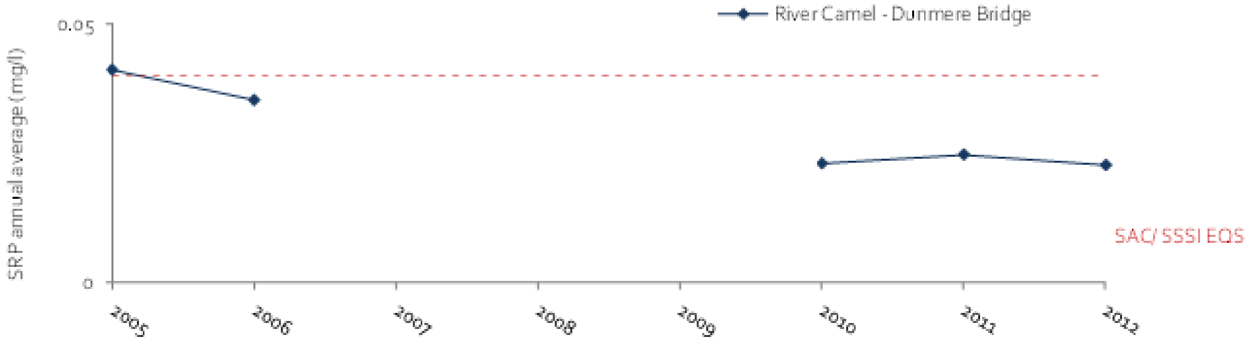
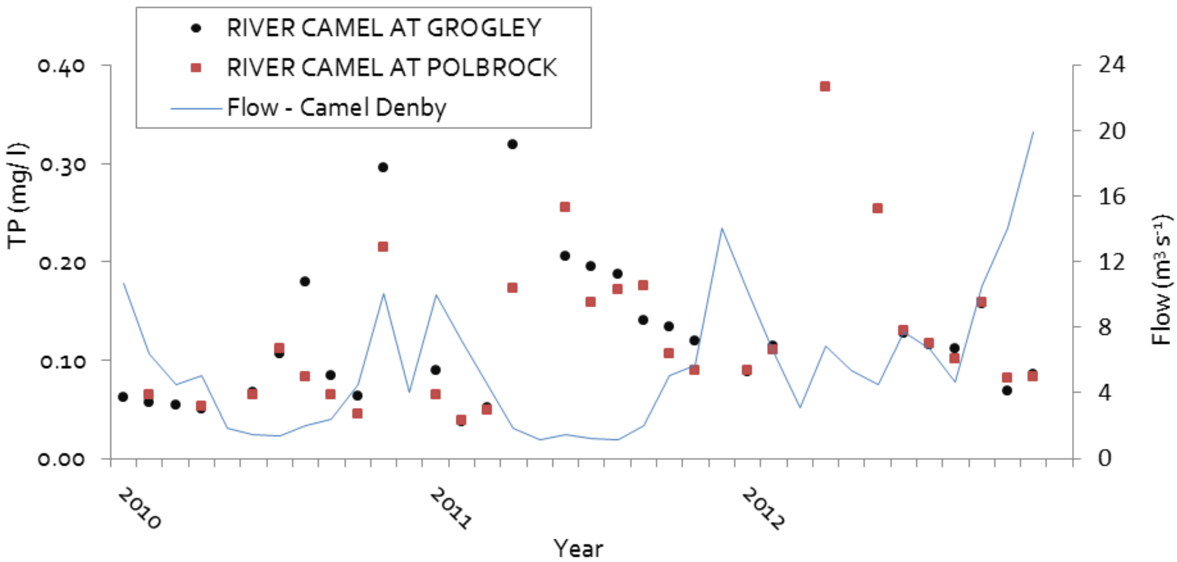


Figure 17: …cont. *Long-term SRP annual average trends in relation to WFD and SAC/SSSI Environmental Quality Standards (EQS) in the Camel catchment.*



When total phosphorus is being supplied to waterbodies as diffuse agricultural run-off, we would expect it to be correlated with flow. A strong correlation was not found between flow and total phosphorus at two measured sites between 2010 and 2012 (Figure 18). This indicates that point sources such as septic tanks and discrete slurry spills are also likely to be an important source of total phosphorus to the watercourse.

Figure 18: *Total phosphorus and flow relationship (data source EA: 2010 – 2012).*



5.2.2. Phosphorus risk analysis

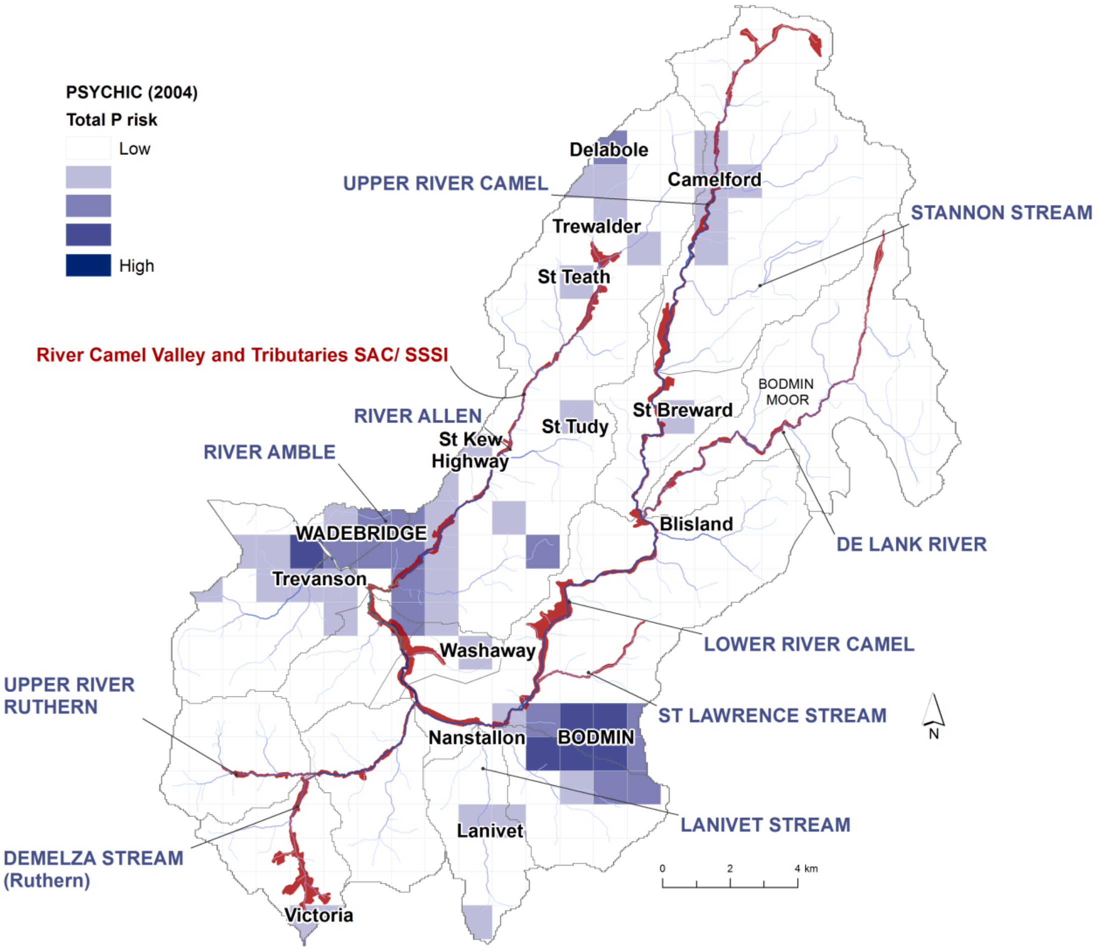
To assess the distribution of phosphorus pollution risk across the Camel catchment, we have used the **P**hosphorus and **S**ediment **Y**ield **CH**aracterisation **I**n **C**atchments (**PSYCHIC**) model developed by a consortium of academic and government organisations led by ADAS (Davison et al., 2008).

PSYCHIC is a process-based model of phosphorus and suspended sediment mobilisation in land runoff and subsequent delivery to watercourses. Modelled transfer pathways include release of desirable soil phosphorus, detachment of suspended solids and associated particulate phosphorus, incidental losses from manure and fertiliser applications, losses from hard standings, the transport of all the above to watercourses in under-drainage (where present) and via surface pathways, and losses of dissolved phosphorus from point sources.

The model can be used at two spatial scales: the catchment scale, where it uses easily available national scale datasets to infer all necessary input data, or at the field scale, where the user is required to supply all necessary data. The model is sensitive to a number of crop and animal husbandry decisions, as well as to environmental factors such as soil type and field slope angle. The catchment-scale model, which has been used here, is designed to provide the first tier of a catchment characterisation study, and is intended to be used as a screening tool to identify areas within the catchment which may be at elevated risk of phosphorus loss.

The PSYCHIC output in Figure 19 serves as an illustration in this report, as the data is from 2004.

Figure 19: *Total phosphorus risk maps derived from the PSYCHIC phosphorus risk model.*



5.2.3. Point sources – agriculture

Point sources of nutrient pollution from agricultural sources include farm infrastructure designed to store and manage animal waste and other materials such as animal food. Key infrastructure includes dung heaps, slurry pits, silage clamps, uncovered yards, feeding troughs and gateways. Animal access points to the watercourse can also lead to the direct delivery of P compounds to the water and to their mobilisation following channel substrate disturbance.

We have consulted farm advisors, who have reported that lack of slurry storage is a potential problem in the Camel catchment. In addition, livestock poaching and watercourse access maybe contributing to point sources of P within the Camel catchment.

Efforts have been made to fence off rivers to discourage poaching and voiding. However, due to the cost of infrastructure such as bridges, pathways and access to rivers is still a problem in smaller streams within the Camel catchment.

5.2.4. Diffuse sources – agriculture

When manure, slurry or chemical phosphorus-containing fertiliser are applied to land prior to or following rainfall it can run-off into a watercourse. Intensive farming of heavy soils or the absence of a cover crop during wet periods increases the likelihood of fine sediment and associated phosphorus mobilisation and transfer.

The intensive farming practices undertaken throughout the Camel catchment present a potential risk of phosphorus transfer to the receiving waters. The landuse data shown previously indicate that there are significant areas of improved/temporary grassland and arable production throughout the catchment which present a potential source risk.

5.2.5. Point sources – consented & unconsented discharges

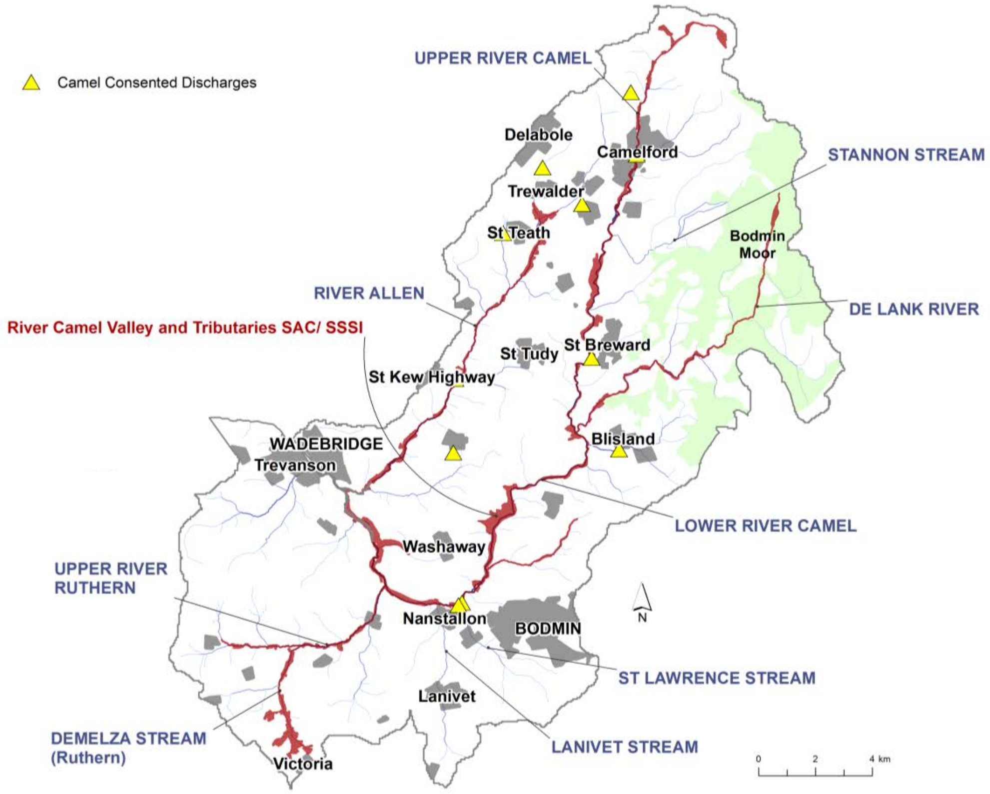
Treated sewage effluent presents another significant source of readily bioavailable phosphorus delivered directly to the receiving water via an end-of-pipe discharge. The principal sources of phosphate in sewage are human faeces, urine, food waste, detergents and industrial effluent which enter the sewer system and are conveyed to a sewage treatment works (STW).

Typical sewage treatment processes generally remove 15-40% of the phosphorus compounds present in raw sewage. Advanced / tertiary treatment, usually in the form of chemical dosing with a precipitant (e.g. Iron or Aluminium Sulphate), can remove up to 95% of phosphorus compounds. In rural catchments like the Camel with a relatively small and dispersed population there are many smaller sewage treatment facilities (sewage treatment works or septic tanks). Both in isolation and combined these can make a significant contribution to in river phosphorus loads and concentrations, both locally and to the overall catchment budget. As point discharges the relative contribution of these sources tend to increase during base / low flow periods as a result of a lower dilution ratio.

The effluent discharge points of many sewage treatment facilities now have an environmental permit or discharge consent associated with them, but there are still many small STWs and septic tanks which are not registered and which do not have a numerical discharge consent.

Camelford and Scarletts Well STW's were fitted with P-stripping capabilities in April 2008. In Figure 20 we see that annual average SRP concentrations decreased dramatically after P stripping was put in place. There was a maximum 98.9 % decrease in SRP concentrations in the River Allen at Sladesbridge and minimum 38.6% decrease in the River Camel at Dunmere Bridge between 2006 and 2008. While P stripping is likely to have contributed to reductions in P load, a similar reduction in SRP concentrations above Camelford STW indicate that other factors such as landuse change may also be an important factor for P reduction.

Figure 21: *Distribution of consented discharges in the Camel catchment.*

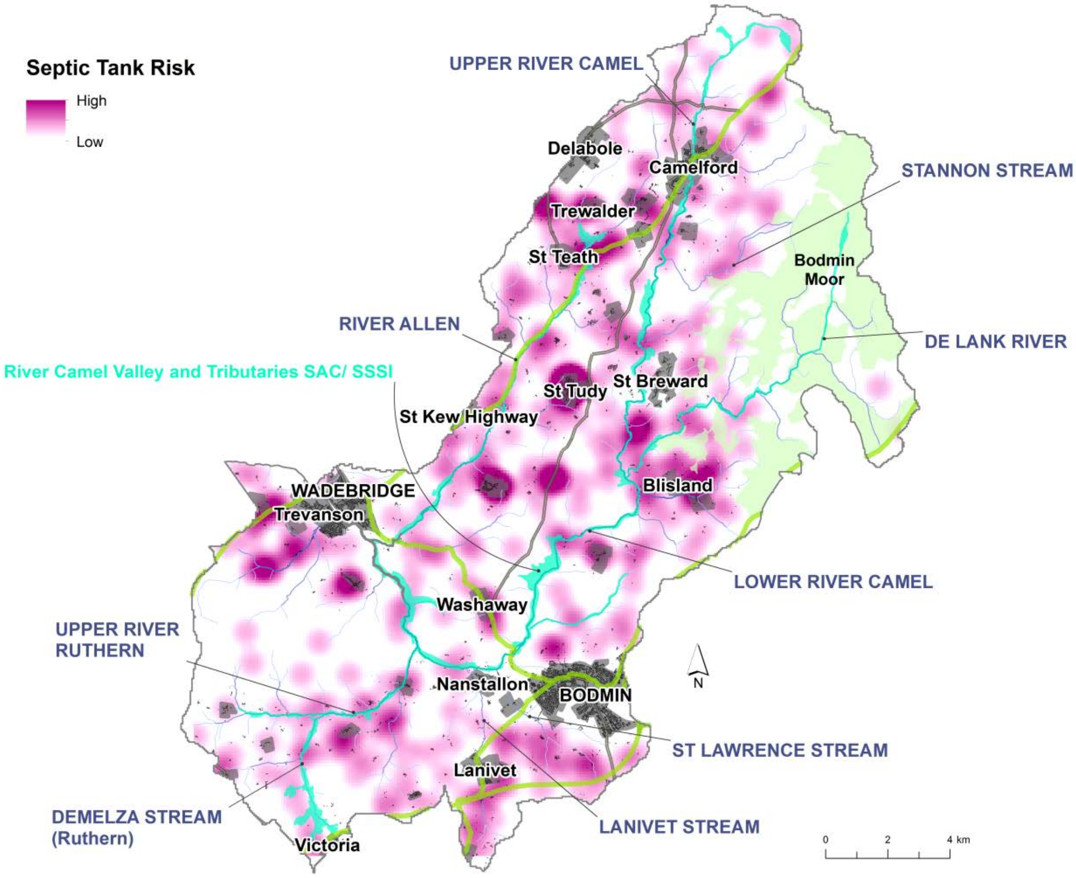


As Figure 22 illustrates, there are a number of additional potential point sources which could be making significant nutrient contributions to the watercourses in the catchment and having some impact on their ecological health and, potentially, contributing to degradation in the Camel SAC/SSSI.

Among these point sources are a number of properties which may have unconsented septic tank discharges. An analysis of property locations compared to the South West Water sewerage network and the Environment Agency Consented Discharges datasets reveals that there are ~928 properties further than 250m from both a sewer and a consented discharge and that ~19 of these are within 50m of a watercourse. These potential septic tanks will need to be investigated and checked to ensure they are being operated optimally and that they are not causing significant pollution levels in their immediate downstream vicinity. The distribution of these potential un-consented discharges is shown in Figure 22.

A similar approach to this mapping, with post code locations, could be used to identify specific properties for targeting visits.

Figure 22: *Density of septic tank pollution risk, based on properties without a consented discharge and not on the sewer network.*



5.2.6. Pollutant load analysis

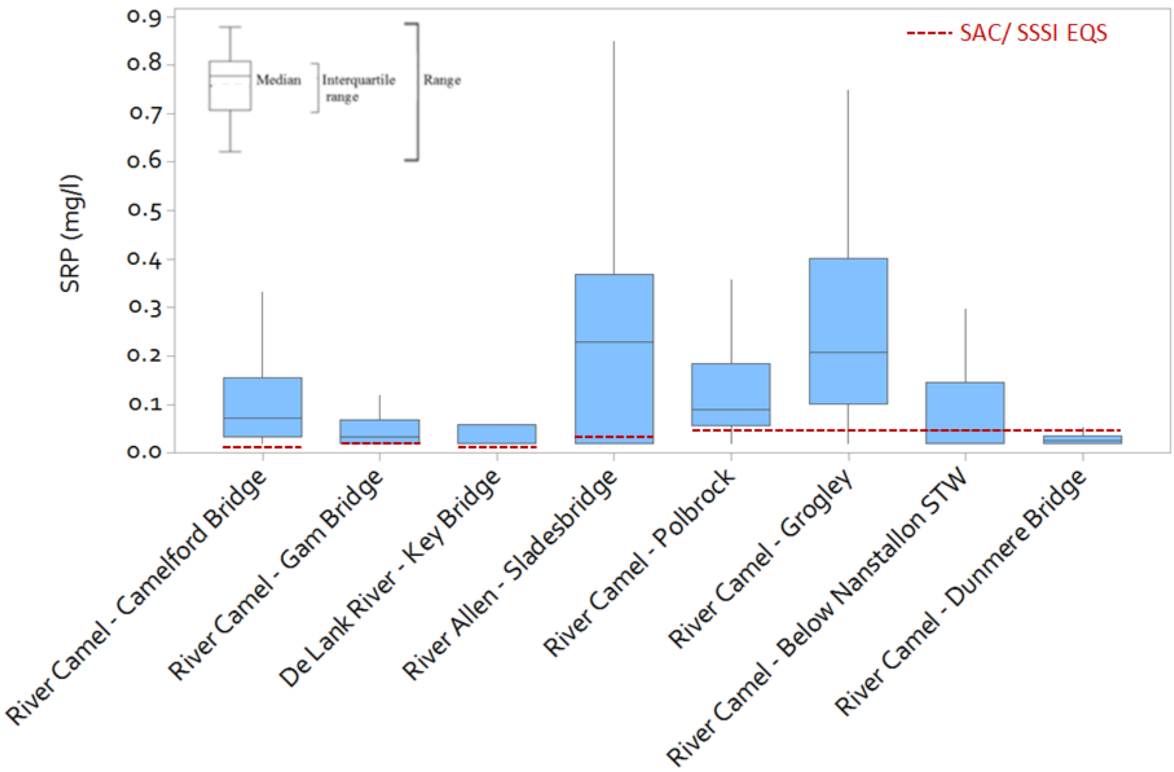
Having characterised where the greatest phosphorus export risk may be present in the Camel catchment, Environment Agency water quality monitoring data collected at 6 locations in the catchment between 2009 and 2012 was assessed to identify which areas were making the greatest contribution to in-stream phosphorus concentrations / loads.

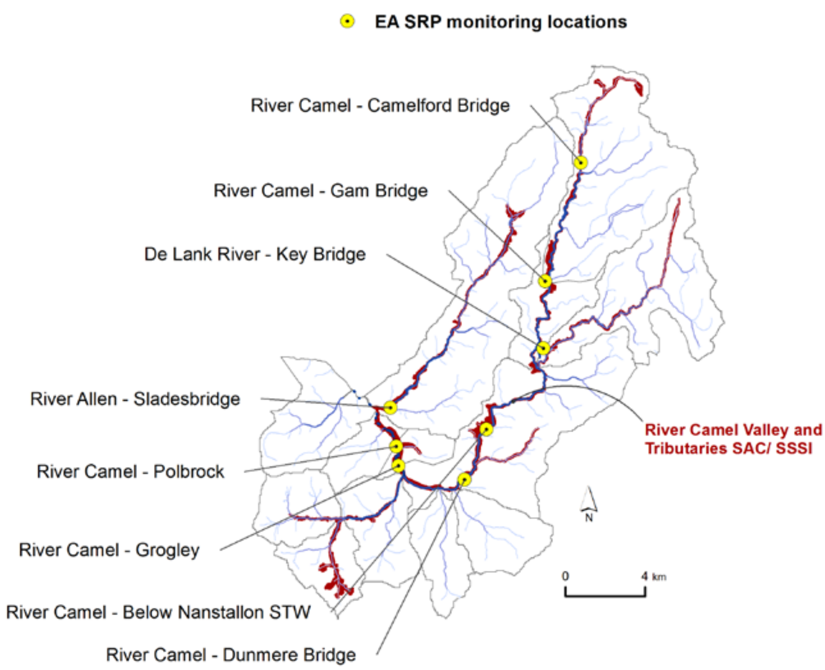
Figure 23 shows the average SRP concentration (the measure used by the Environment Agency for WFD status) recorded between 2009 and 2012. Figure 24 shows average total phosphorus (TP) concentrations measured by the Environment Agency at two locations. The Environment Agency does not routinely measure total phosphorus in their statutory monitoring programme.

This data shows that the average levels of SRP exceed SAC/SSSI (0.04 – 0.06 mg/L) and WFD targets (0.12mg/L) across 4 of the 8 of the monitoring locations in the catchment between 2009 and 2013. SRP concentrations >0.08 mg/ L can lead to algal blooms. The highest recorded average SRP concentrations were found in the River Camel at Grogley and Polbrock, with the largest range at Sladesbridge. Targeted delivery of intervention measures in these sub-catchments has the greatest potential to reduce elevated phosphorus concentrations in the River Camel SAC/SSSI.

Not all water quality monitoring points had long-term comparable SRP data. Thus, only those which haddata between 2005 – 2012 were included in Figure 17. The water quality monitoring points used in Figure 23 are not all the same as those in Figure 23, which used sites with SRP data for 2009 – 2013.

Figure 23: *Variation in soluble reactive phosphorus concentrations at 6 locations in the Camel catchment from 2009 – 2013, (data source: EA).*





5.2.6. Source Apportionment

There are a number of models available that can be used to estimate the relative contribution to in river phosphorus loads and concentrations from different sources / sectors. These estimates help to put the diffuse source contribution in context with that of other sector sources and are thus useful in targeting measures at the dominant sources / sectors. In many cases it may be a combination of measures across multiple sources is required to meet a conservation objective.

The output from two such models has been made available to inform this project, these are:

- **Source Apportionment GIS (SAGIS)** – A high level modelling framework based on the best available datasets with National coverage. SAGIS has predominantly been used for strategic planning, for example to inform policy decisions or run scenarios at the National or regional scale. The model has been refined "localised" in some regions / catchments but not yet in the southwest so the outputs made available for this study are based on default data and have only been calibrated at the National scale.

- **SIMCAT** – Setup on the Camel catchment by local Environment Agency staff with specific knowledge of the catchment, water industry assets and industry discharges. The initial driver for developing this model was to support the Habitats Review of Consents process, though the model has since been updated in 2010 to inform river basin planning.

Outputs from both models provide a comparative assessment of the contribution from point versus diffuse sources and thus are useful in informing the extent of the measures required across these sectors and where these are best targeted. However, outputs in this document do not provide a direct comparison, as SAGIS and SIMCAT are calibrated at different scales (national vs catchment) and time periods (2005 – 2009 and 2006 – 2008, respectively). Figures 24 (a) and (b) show the predicted verses observed SRP concentrations for the periods modelled in SAGIS and SIMCAT.

Figure 24 (a): *Modelled verses observed SRP concentrations from SAGIS modelling for the Camel catchment for 2005 - 2009. *: observed SRP monitoring data not available. Map with monitoring and modelling locations inset.*

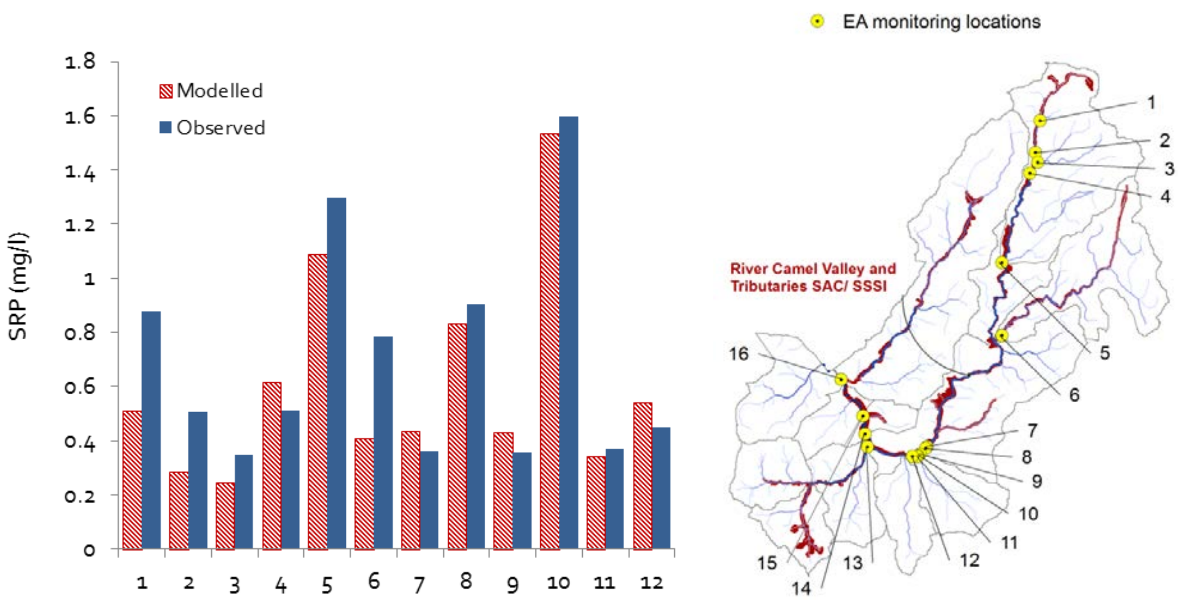
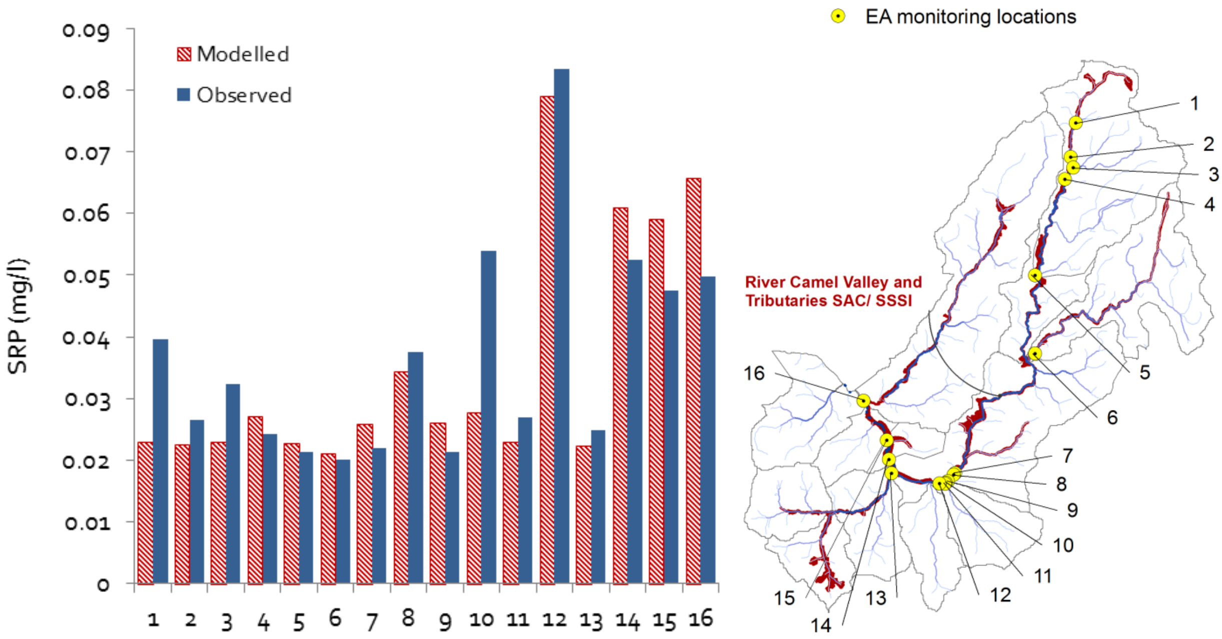


***Figure 24 (b)**: Modelled verses observed SRP concentrations from SIMCAT modelling for the Camel catchment for 2008 - 2011. *: observed SRP monitoring data not available. Map with monitoring and modelling locations inset.*



SAGIS

SAGIS is able to directly estimate contributions from different sector sources based on observed / modelled data, rather than by difference. However, in the National phosphorus calibration, made available for this study by the Environment Agency, point sources are treated as known and diffuse inputs amended, whilst preserving the relative contribution between different sectors.

The model output is calibrated against observed in-stream annual average concentration and also lumps together agricultural livestock and arable sectors with urban diffuse contributions, thus estimating the total diffuse contribution.

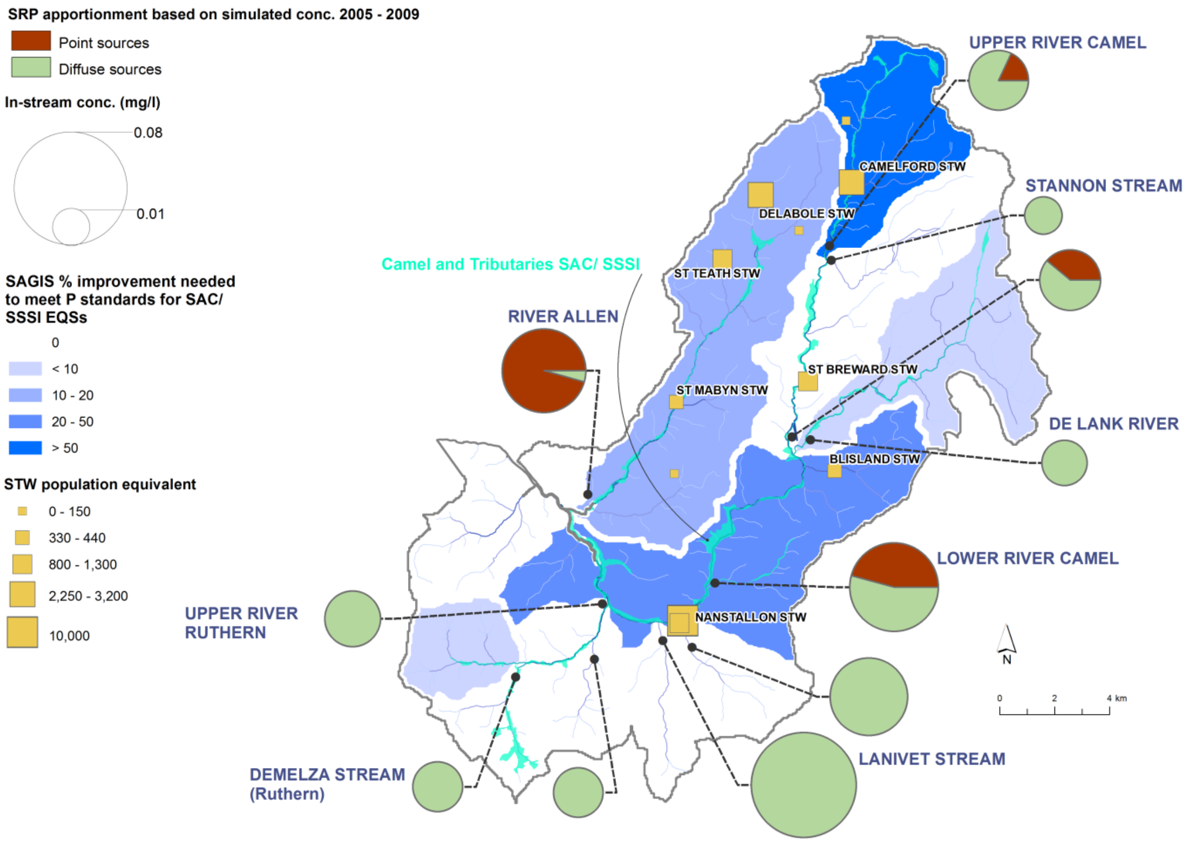
Figure 25 shows modelled SAGIS source apportionment outputs for 2005 to 2009, categorised as point sources (STWs and septic tanks) and diffuse (agricultural and urban). Source apportionment charts at modelled sites have been displayed proportionally depending on modelled average P concentrations for the period (2005 – 2009). Figure 25 provides an indication of the extent of the improvement required, in percentage terms, to meet SAC/ SSSI EQS targets.

Modelled SAGIS outputs indicate that diffuse sources are the main overall contributor of P pollution in the Camel catchment, particularly in the North-East and lower reaches of the catchment. While diffuse sources in SAGIS are lumped as both agricultural and urban sources, agriculture dominates then landuse so can be safetly assumed to be the main diffuse P source in the Camel catchment.

SAGIS outputs suggest that the River Allen and both Upper and Lower Camel sub-catchments have significant (>30%) P inputs from STWs. The River Allen monitoring point is downstream of Delabole, St Teath and Helston STWs which service estimated populations of 2256, 1051 and 161 respectively.

Septic tank loads are considered low (<10%) across all sites, with inputs occurring in the southeast corner of the catchment. These are coincident with the areas where a high septic tank risk was highlighted (Figure 22), particularly around Blisland and Nanstallon.

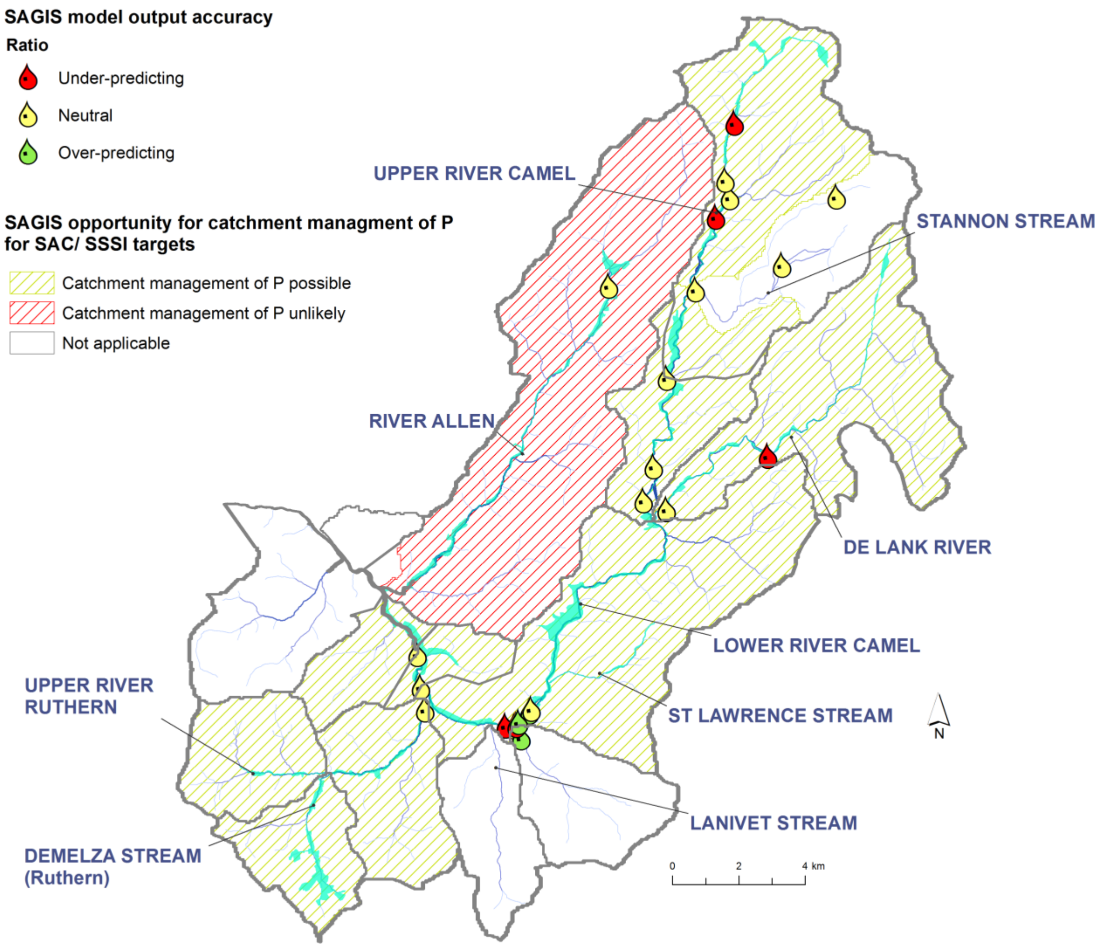
***Figure 25**: SAGIS source apportionment and % P improvement required to meet SAC/ SSSI EQS's in Camel catchment sub-catchments (2005 – 2009).*



The opportunity for catchment management, i.e. management of diffuse P sources rather than point sources of P has been defined for each sub-catchment in Figure 26. Opportunity for P management is dependent on both: the modelled P inputs from diffuse agricultural and urban sources; and the average modelled P concentrations relative to SAC/ SSSI EQS standards. If the percentage improvement needed to meet SAC/ SSSI EQS's for P is less than 50 % and the amount of P from diffuse sources is greater than 50 % then catchment management of P is deemed possible, and vice versa. Sub-catchments are not applicable to P management where P concentrations are within SCC/ SSSI EQSs.

Figure 26 also gives an indication of the accuracy of the calibration against observed Environment Agency monitoring data for 2005 - 2009.

Figure 26: SAGIS P mitigation opportunity map and model output accuracy for the Camel catchment.



The analysis displayed in Figure 26 indicates that catchment management of P is possible in all measured sub-catchments except for the Allen. Catchment management of P to meet SAC/ SSSI EQS's has been deemed unlikely in the Allen sub-catchment because a 96% contribution from STWs has been modelled in SAGIS. Thus, catchment management of diffuse agricultural P sources will have little effect on in-stream P concentrations. Where P management is possible reductions in measured P concentrations and modelled diffuse P sources are less than and greater than 50% respectively. However, SAGIS only includes P-stripping at at Camelford and Scarletts Well and does not include P-stripping which was installed at STW's in the Camel catchment after 2009. Thus, apportionment and management of P is likely to be different under recent management initiatives.

SIMCAT

SIMCAT model outputs have been derived for the SIMCAT National models (SW18 National Model). Modelling was carried out over two time periods i.e. 2001 – 2005 and 2008 – 2011, to estimate pre and post P stripping impacts from diffuse and point source discharges on P concentrations. Source apportionment has been investigated using SIMCAT for the period 2008 – 2011. The source apportionment outputs are based on exit points on modelled water bodies with all discharge permits operating at fully licenced flows (DWF * 1.25).

Based on SIMCAT modelling for the period between 2008 and 2011 modelled P concentrations exceed favourable condition target and progress goal measures in all waterbodies. However, modelled P concentrations in the De Lank and Ruthern waterbodies only marginally exceed SAC/ SSSI EQS's.

Modelled P concentrations in the mid Camel (De Lank to Stannon Strem), River Allen and Lower Camel waterbodies exceed SAC/ SSSI EQS's by 0.015 – 0.019 µg/l. In the mid Camel, the point: diffuse source ratio has been modelled at 51: 49. Overall, SIMCAT modelling results indicate that management of point sources of P acts as a priority measure where non-compliance with SAC/ SSSI standards exists.

In the mid Camel, modelled point source P reductions could be achieved through improved treatment at St Breward STWs. 48 percent of modelled diffuse P in the mid Camel has been attributed to agricultural sources. Reductions in the diffuse P component could be achieved through long-term application of on farm best practice measures.

Modelled P source apportionment outputs for the River Allen sub-catchment were 58 % and 42% from point and diffuse sources respectively. However, the output from SIMCAT is at the outflow of the sub-catchment, and therefore the uupstream benefits point source reductions for STWs are not accounted for. Figure 27 shows that Delabole, St Teath and Mabyn STWs contribute to non-compliance of P concentrations in the upstream reaches of the River Allen. As agricultural diffuse P inputs are relatively low at 0.018 µg/ l, management of point sources would likely provide the most effective reductions to instream P concentrations. Management of point sources in the Allen sub-catchment would likely include implementation of P-stripping at St Mabyn STW and improved treatment at Delabole STW.

Point sources from the Lower River Camel have been modelled as the main source of P, with a point: diffuse ratio of 70: 30 percent. Figure 28 indicates that P concentrations increase significantly in the upstream reaches of the catchment, towards Nanastallon STW in Bodmin. These results show that compliance with SAC/ SSSI EQS's in the Lower Camel will only be possible if P stripping is implemented at Nanstallon STW. P stripping at Nanastallon STW has already been proposed for PR14. P stripping scenario modelling indicated that the P impact from Nanastallon STW could be reduced from a current peak of around 80 µg/ l to around 50 µg/ l in the river Camel.[1]

[1] Calibration of the SIMCAT model against observed monitoring data in the Camel did require an unusually high in-stream decay rate (1 versus 0.1-0.2 which is commonly used as the default). This could be indicative of very high removal rate of SRP from the water course or reflect uncertainty associated with other aspects of the model or underlying data. This could include under-estimating travel times and / or over-estimating input loads. This calibration reflects the uncertainty associated with the data and underlying model assumptions and it is important to recognise the limitation of this and indeed any models and that they form only one strand of the weight of evidence on which effective targeting of advice and measures should be based.

Figure 27: *Mean pre and post P stripping P profiles down the Delabole Stream and River Allen (2008 – 2011). Set against WFD EQS's. Source: Murdoch, EPM QW EA SW – River Camel SIMCAT Model (2001).*

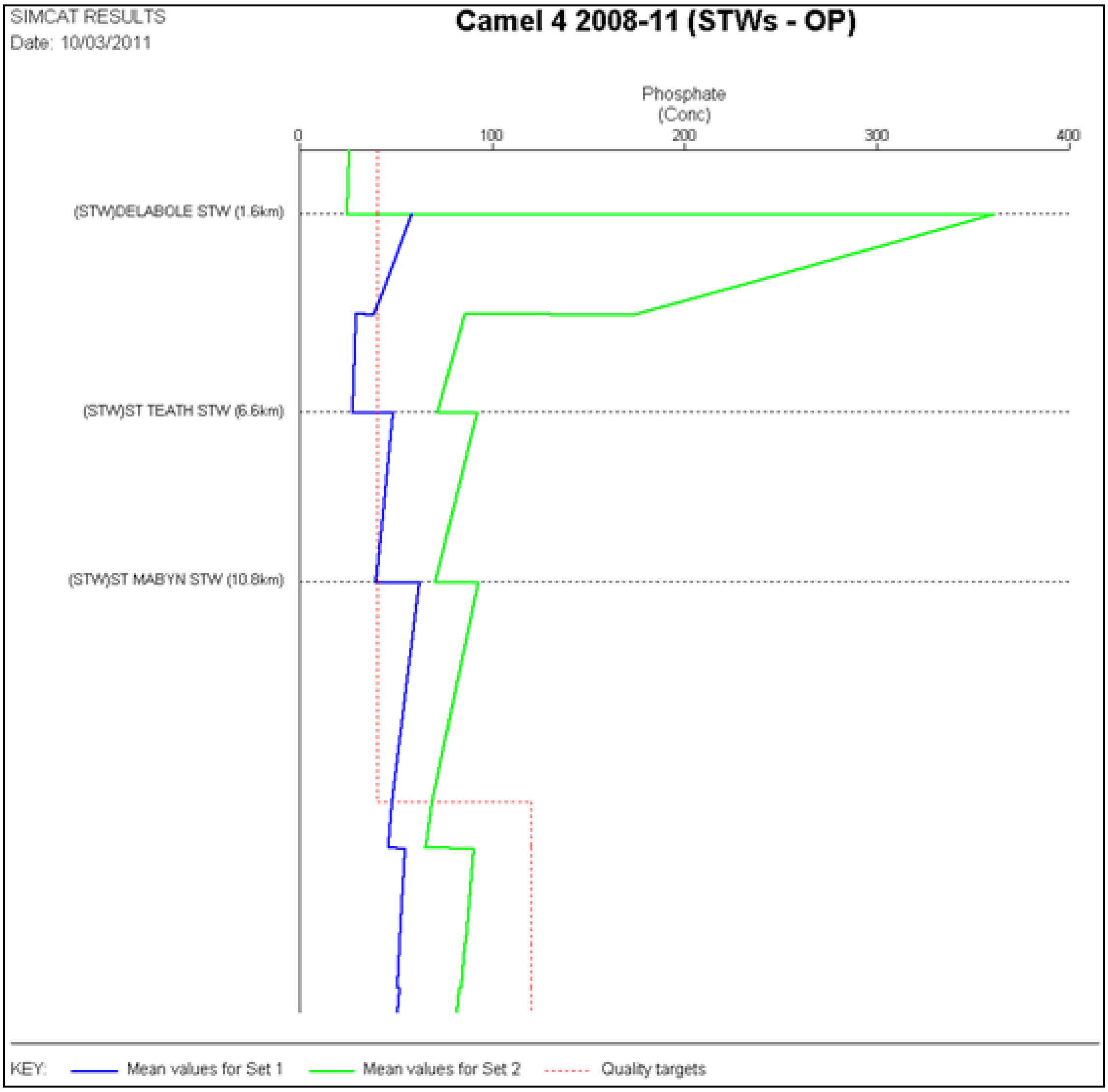


Figure 28: *Mean pre and post P stripping P profiles down the River Camel (2008 – 2011). Set against WFD EQS's. Source: Murdoch, EPM QW EA SW – River Camel SIMCAT Model (2001).*

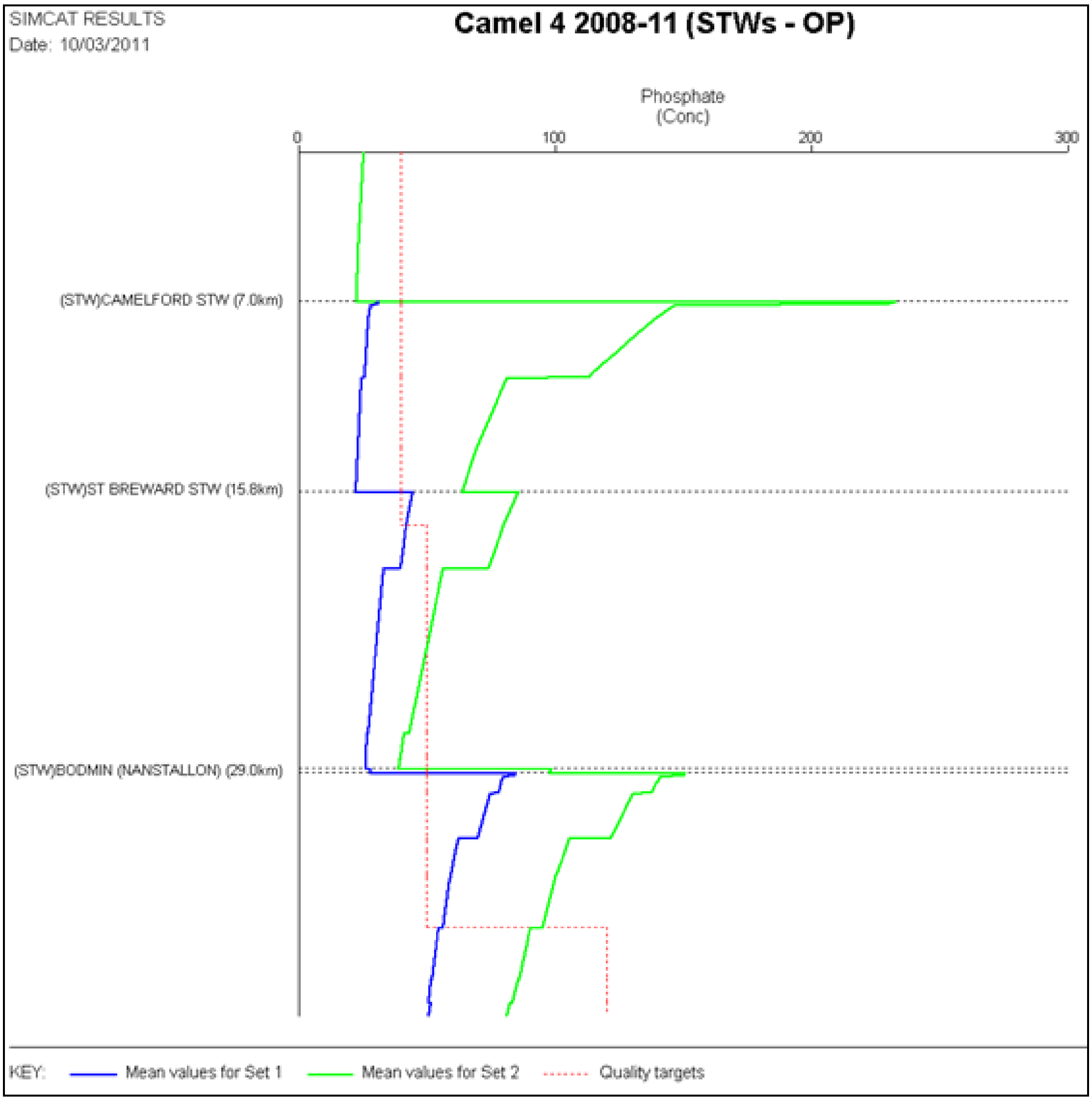
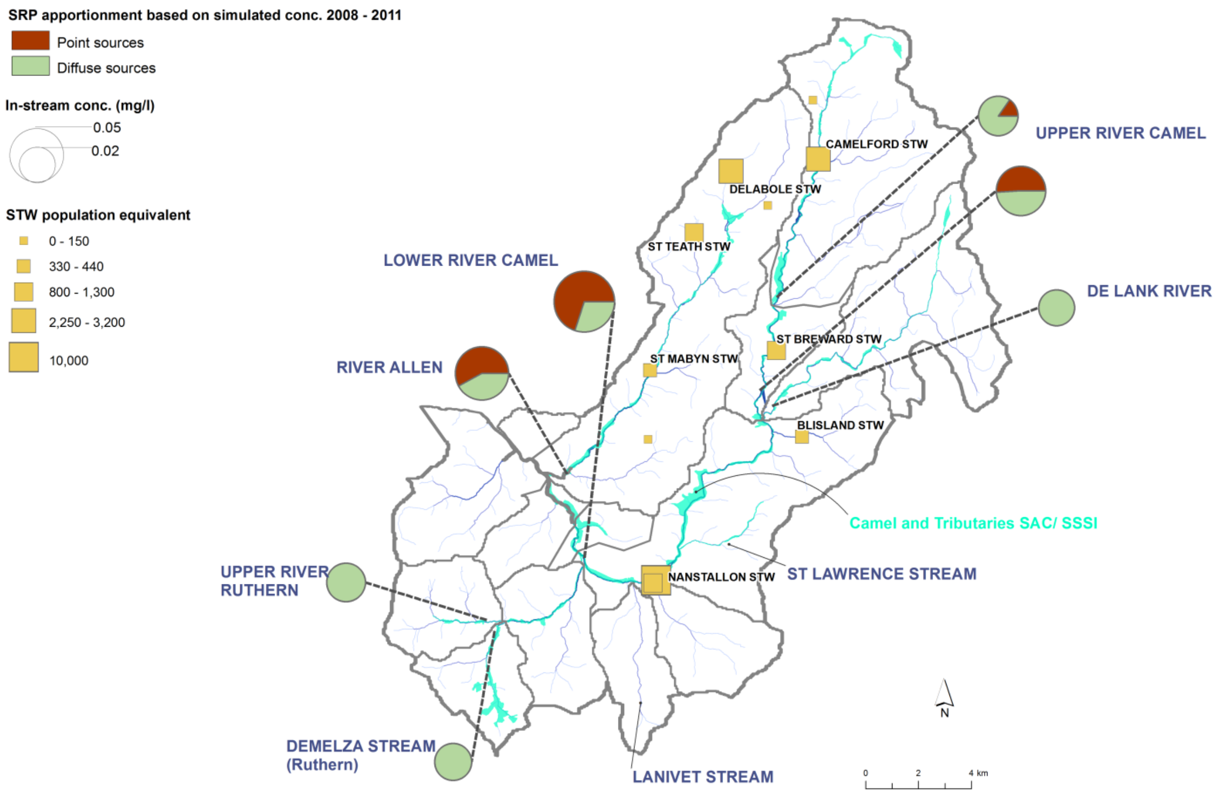


Figure 29: SIMCAT source apportionment for the Camel catchment.



It is important to note that outputs from SAGIS and SIMCAT are not directly comparable as reflected by the difference between the outputs, the different model periods, base data and underlying assumptions, as well as the extent of the calibration (i.e. National for SAGIS versus local for SIMCAT).

Model assumptions and the input data itself will also lead to uncertainty in the model outputs. However, the differences between outputs do provide an indication of the uncertainty associated these catchment scale models. Despite these issues output from both models are generally in good agreement in most waterbodies, both illustrating the significance of point sources in the mid Camel, River Allen and Lower Camel sub-catchments.

SAGIS does tend to over-estimate concentrations in a number of headwater catchment, which in catchments of similar typology to the Camel have been found to be a result of how the loads are allocated across the hydrograph and in accuracy in the flow predictions in un-gauged headwater tributaries. This can be corrected through calibration the relationship between diffuse loads and flow at the catchment scale.

Effluent concentrations and flows behind SAGIS are based on continuous flow monitoring for MCERTS and where available, spot water quality samples. In the absence of a local calibration it is not possible to ensure that SAGIS captures the latest consent conditions and that all discharge points are correct. Although SIMCAT also uses observed data to derive summary statistics for effluent concentrations, flows reflect those in the consent (DWF * 1.25).

In the absence of access to the models themselves or the data that sits behind them it is difficult to identify the definitive reason behind all differences. Outputs from these models should therefore be treated with caution although they do form an important element of the weight of evidence approach and are particularly useful in predicting the benefits of in combination reductions in the point source loads.

5.2.6. Population Growth

Population growth in the catchment has the potential to affect the relative contribution between point and diffuse sources. Both models rely on observed data summary statistics that best reflect the current effluent concentrations.

SIMCAT uses the consented flow conditions and thus presents the worst case scenario. SAGIS uses actual MCERTS flow monitoring data which for some STW has been found to be higher than consented flows, though it is not clear whether this is the case in the Camel catchment.

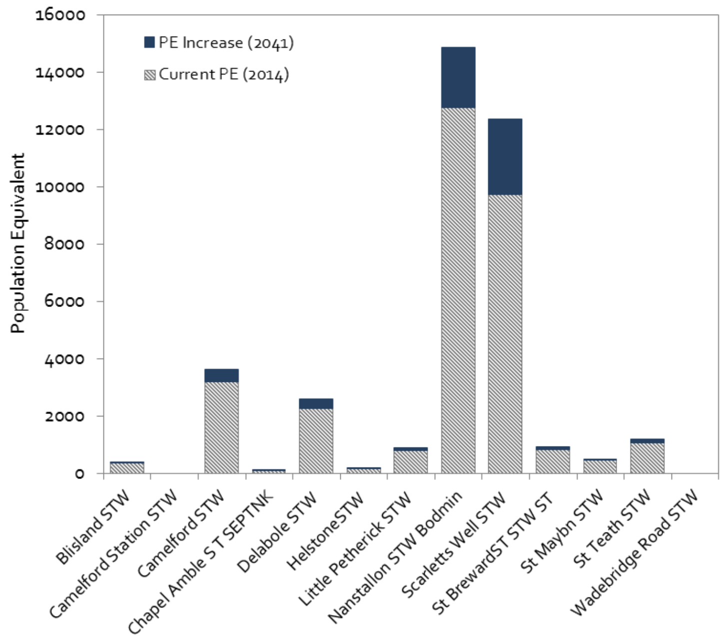
Further planned improvements during AMP6 at Bodmin (Nanstallon STW) include the installation of phosphorus stripping by 2020 to a meet tighter total phosphorus consent of 1 mg/L. These planned improvements have been modelled at fully consented conditions using SIMCAT and show and a reduction in in-stream concentrations from around 0.08 and 0.05mg/L.

The default diffuse concentration used by SIMCAT in the Camel is relatively low and at 0.025 mg/L is below target concentrations in the SAC. A slightly higher concentration (0.075 mg/L) is used for the River Amble tributary.

Where population increase leads to higher flows and thus effluent loads the Environment Agency are likely to require a tightening of the effluent quality in order to achieve load standstill, where effluent flows do exceed the current consent.

Unfortunately data on flow or water quality headroom at individual STW has been requested but has not been provided for this study. However, discussions with SWW do indicate that they do not envisage any difficulties in accommodating growth in the catchment based on known developments and historic population trend data.

Figure 30: *provides a summary of SWW projected growth in population equivalent within each sewerage catchment.*



6. Intervention strategy development

Before we can proceed with the development of a catchment management programme for diffuse pollution within the Camel catchment, we must first gather precise and detailed evidence of what plans are already in place and what interventions have already been delivered across the catchment.

6.1 Prior interventions

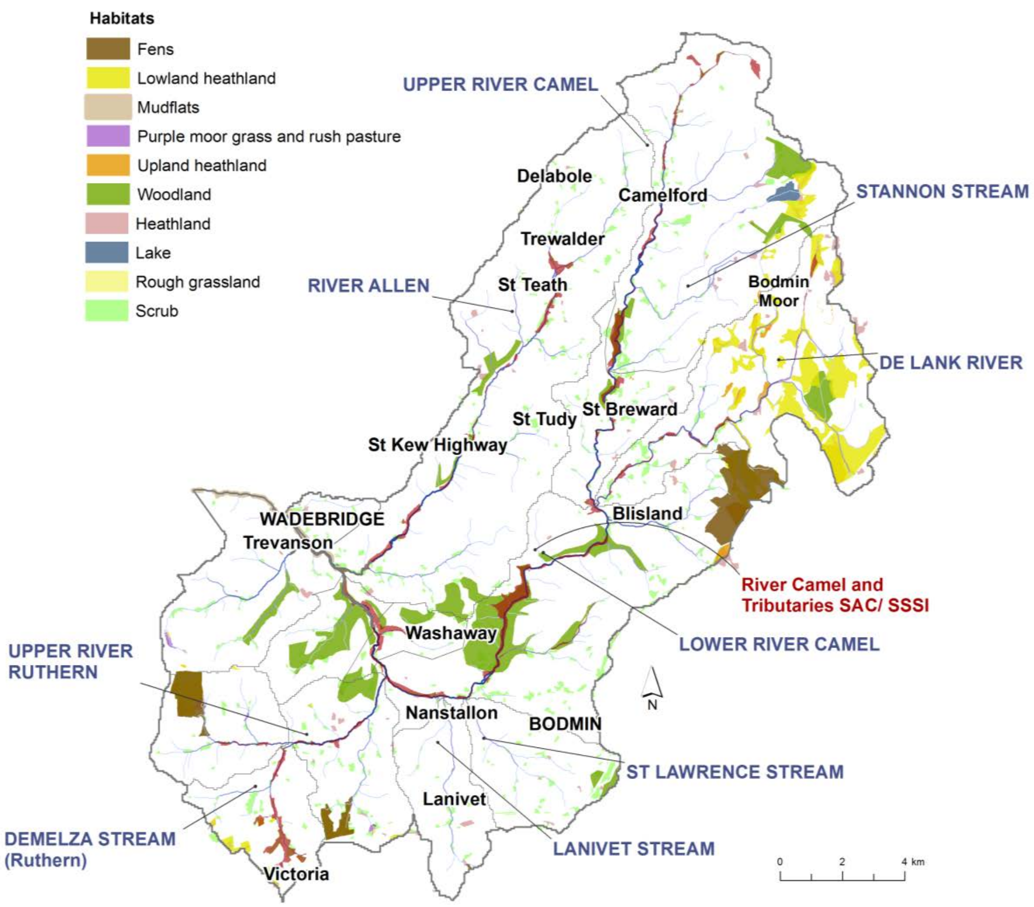
6.1.1. Natural mitigation & designated sites

Natural habitats play a key structural and functional role in the ability of natural ecosystems to provide the services on which we all depend; including the protection of clean, fresh water in rivers and streams, the mitigation of flood risk and the prevention of erosion.

Extending and increasing the connectivity of existing natural habitats across catchments, in addition to the creation of new riparian wetlands to disconnect hydrological pollution pathways, are some of the key methods used in catchment management and natural resource protection.

Data, obtained from the Natural England habitat inventory, indicate that there are: ~532 Ha of Fens; ~1157 Ha of Lowland heath; ~176 Ha of Upland heath; ~4 Ha of mudflats;~12 Ha of Purple moor grass and rush pasture; and ~1556 Ha of woodland in the River Camel catchment.

Figure 31: *Distribution of important natural habitats in the Camel catchment.*



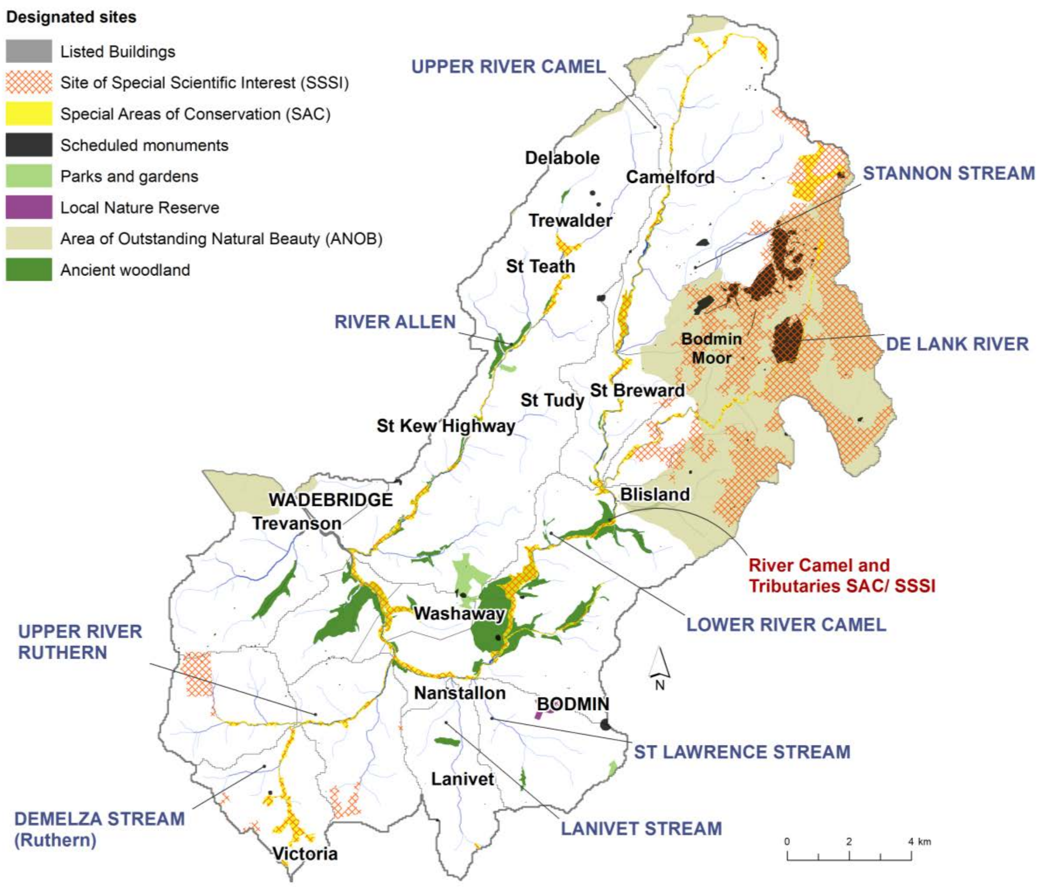
Under the Conservation (Natural Habitats) Regulations 1994, the UK is committed to the designation and protection of three types of internationally important conservation sites: Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar Sites. No SPAs or Ramsar sites exist within the Camel catchment. The SAC designated River Camel and Tributaries forms the only SAC within the catchment.

The designation and protection of land that is important for nature conservation has historically been one of the key methods used to protect and conserve the natural environment in the UK.

In an attempt to increase the benefits obtained from the protection and expansion of the designated site network in the Westcountry, Biodiversity South West are adopting a more integrated landscape-scale approach to nature conservation. They have identified a series of Strategic Nature Areas that are being prioritised for conservation action through active partnership within and beyond the environmental sector. Their objective is to achieve the best environmental return for the optimum investment of resources.

Figure 32 shows the distribution of designated land across the Camel catchment. The Camel estuary is designated as an Area of Outstanding Natural Beauty (ANOB). Including the River Camel site, there are 26 designated SSSI units within the Camel catchment, including forested areas with Ancient woodland within the Camel Valley.

Figure 32*: Distribution of sites designated for the natural or cultural heritage in the Camel catchment.*



6.1.2. Previous on-farm interventions: Environmental Stewardship

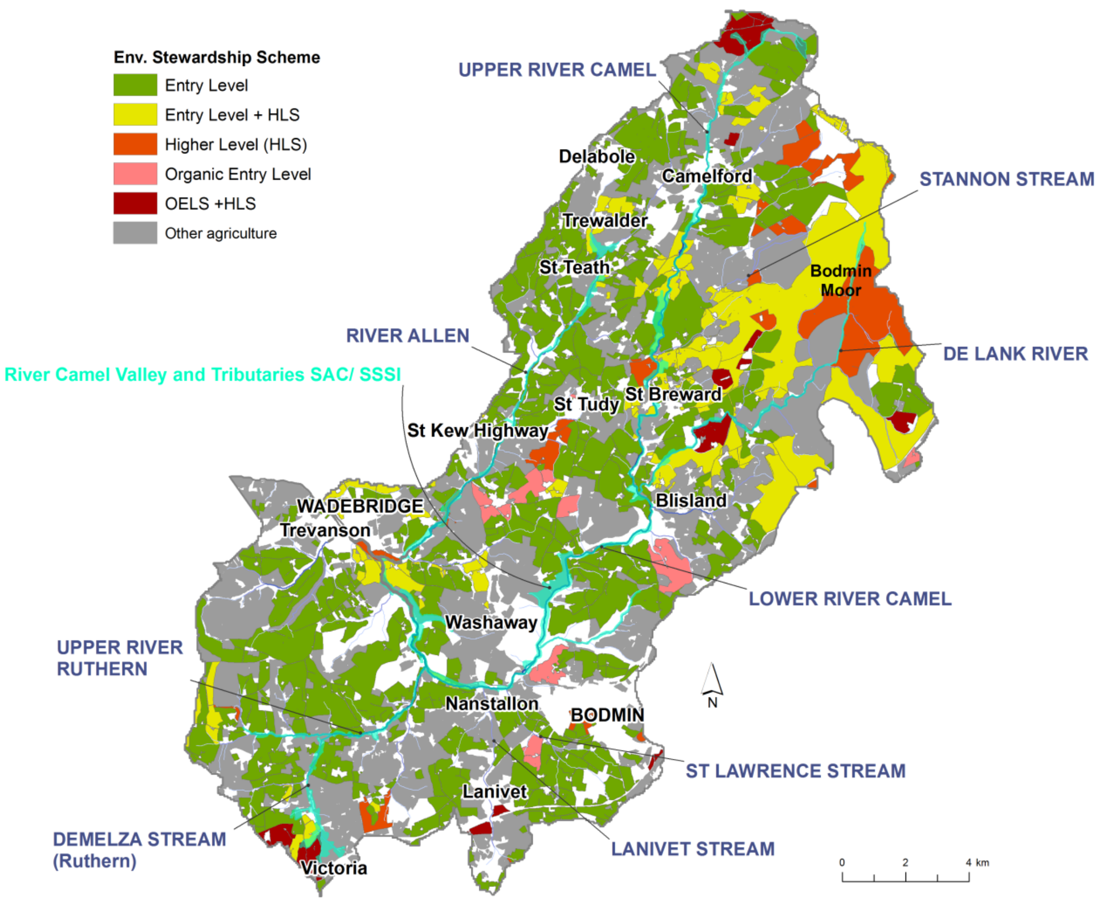
The Environmental Stewardship (ES) Scheme, incorporating the Entry Level Scheme (ELS), Organic Entry Level Scheme (OELS), the Uplands Entry Level Scheme (UELS) and Higher Level Scheme (HLS), provides payments to farmers to undertake specific management practices or capital works that protect and enhance the environment and wildlife.

The ESS is offered to farmers on a voluntary basis and is promoted as multi-objective scheme covering a range of biodiversity, heritage and natural resource protection objectives, including soil and water protection.

The ELS, OELS and UELS are non-competitive schemes and are open to all farmers whilst the HLS is a competitive scheme within which farmers must effectively bid for a share of a limited budget. According to Natural England personnel engaged with the project, HLS currently covers 10% of agricultural land across England and is increasingly focusing on SSSI sites and Habitats Directive designated areas.

Figure 33 shows the distribution of farm holdings currently engaged in an ELS scheme across the Camel catchment. These data indicate that there are 624 farms signed up to an ELS scheme. Around 63 farms in the catchment are in Organic Entry Level or Organic Higher Level Environmental Stewardship schemes, and around 33 are in Higher Level Stewardship. There are around 107 farms in Entry Level plus Higher Level Stewardship and the remainder, around 421, are in Entry Level Schemes.

Figure 33: *Distribution of Environmental Stewardship schemes taken up by farmers in the Camel catchment.*



6.2. Diffuse pollution management

Diffuse nutrient and sediment pollution can result from various urban and rural sources. The catchment characterisation, water quality monitoring and SIMCAT/SAGIS modelling outputs presented in this report indicate that diffuse agricultural pollution makes a significant contribution to the ecologically damaging P and SS pollution in the Camel Catchment.

Therefore, implementation of a targeted diffuse agricultural pollution management plan would most likely provide water quality benefits to the Camel Catchment and, more specifically, the Camel SAC/SSSI. It should be noted, however, that while references are made to all agricultural pollution as a diffuse, other literature sometimes refers to agricultural sources with discrete pathways, e.g. tile drainage and slurry spills, as point sources.

In order to manage agricultural pollution an established 'toolbox' of Best Farming Practices (BFPs) have been developed, which can be used to target P and SS pollution. When effectively implemented, BFPs can have a wide range of additional secondary environmental, social and economic benefits. For instance, a number of interventions used to tackle P and SS involve creation and enhancement of natural features, such as riparian buffer strips, which can provide habitats along with reducing pollution transport to water courses.

Habitat creation and subsequent biodiversity improvements in the wider catchment can improve biodiversity in the SAC/SSSI by reducing fragmentation and increasing genetic diversity and species networks. Furthermore, reduction of pollutants such as nitrogen, specifically nitrate, which is often associated with P sources, is a common secondary benefit of BFPs.

In designing BFP scenarios for P pollution, it is important to consider the form or species of P that is being targeted. Whilst the monitoring and modelling data in this report focus on SRP (dissolved P) concentrations in water, most P pollution from agricultural practices is supplied to watercourses in a particulate-bound form. Once in the watercourse, particulate P can be chemically and biologically mobilised into the bioavailable SRP form. Therefore, interventions aim to reduce both particulate and dissolved P. As particulate P is often associated with sediment, BFPs aimed at reducing particulate P pollution may also have high potential to reduce SS pollution and vice versa.

The BFP 'toolbox' interventions are presented in Figure 34, where 'bad' farming practices are illustrated on the left, and 'good' farming practices on the right. Figure 35 provides a series of before and after photographic examples of on-farm interventions of this type.

Figure 34: *Illustration of Best Farming Practices (BFPs) that can minimise loss of pollutants to watercourses as a result of agricultural activity.*

Soil management

- (A) Cultivate and drill across the slope
- (B) Avoid over-winter tramlines
- (C) Establish in-field grass buffer strips
- (D) Adopt minimal cultivation systems
- (E) Avoid high risk crops next to river

Livestock management

- (A) Reduce overall stocking rates on livestock farms
- (B) Reduce field stocking rates when soils are wet
- (C) Move feeders and water troughs at regular intervals
- (D) Construct troughs with a firm but permeable base
- Reduce dietary N and P intakes

Fertiliser management

- (A) Do not apply fertiliser to high-risk areas
  Avoid spreading fertiliser to fields at high risk time
- (B) Use clover in place of grass

Farm infrastructure

- (A) Fence off rivers & streams from livestock
- (B) Construct bridges for livestock crossing streams
- (C) Re-site gateways away from high-risk areas
- (D) Farm track management
- (E) Establish new hedges
- (F) Establish Riparian buffer strips
  Establish & maintain artificial wetlands

Manure management

- (A) Increase the capacity of farm manure (slurry) storage
  Install covers on slurry stores
- (B) Site manure heaps away from watercourses
  Site manure heaps on concrete and collect effluent
- (C) Minimise volume of dirty water and slurry produced

Figure 35: *Actual examples of Best Farming Practices (BFPs) that can minimise loss of pollutants to watercourses as a result of agricultural activity.*

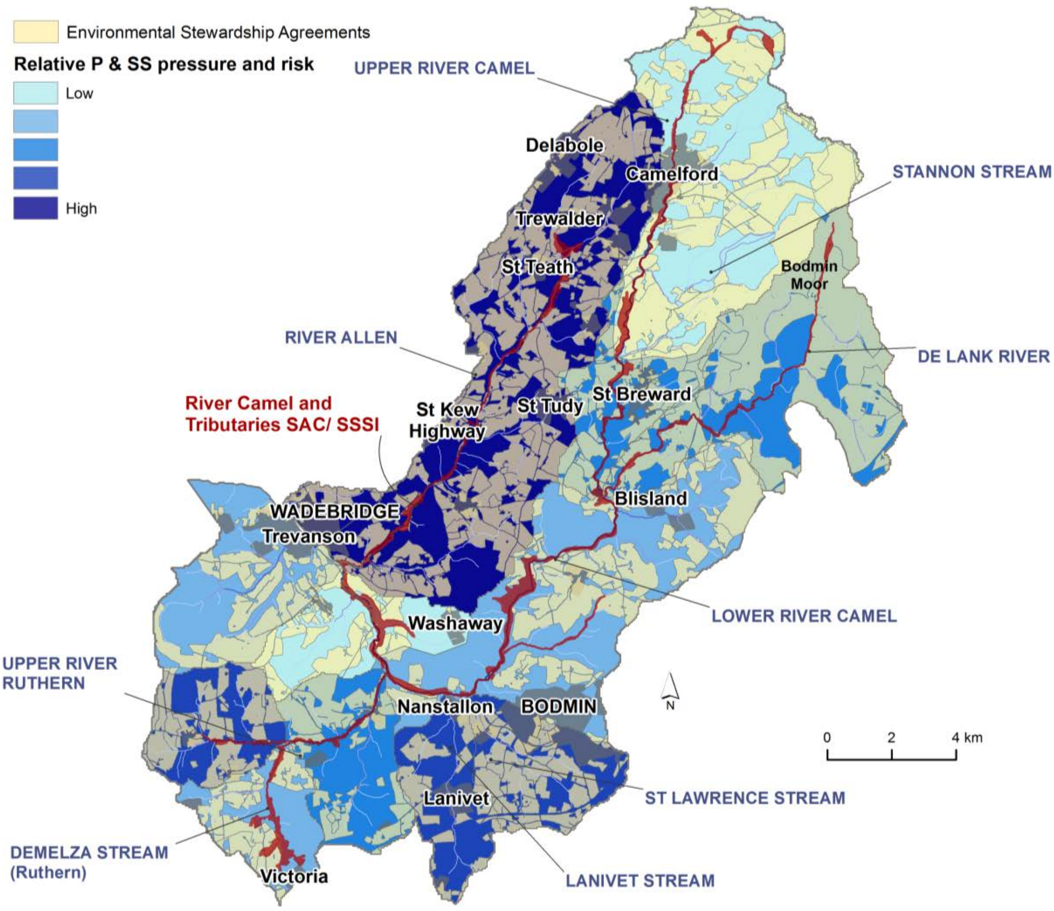
The mapping, modelling and water quality analyses set out in this report have highlighted that diffuse P and SS pollution generally occur in the mid and lower reaches of the Camel catchment. Thus, application of BFPs could be carried in identified high risk areas within the catchment to achieve necessary P and SS reductions. The GIS analysis of P and SS monitoring and modelling, along with current interventions help to identify areas in the catchment where application of BFPs may result in greatest, and possibly more cost effective, reductions P and SS. The results of this analysis are presented in Figure 37.

The map of high BFP impact locations involved firstly identifying areas with the greatest P and SS pressures and risks. Sites were then identified with the highest: (1) empirical SRP and SS concentrations from averaged EA monitoring data (2011 – 2013); (2) fine sediment erosion risk (top 10% risk from 10m SCIMAP); and (3) diffuse SRP inputs modelled in SAGIS and SIMCAT. High P and SS risk areas have been identified on a sub-catchment basis to align the sampling and modelling resolutions of the underlying data.

To illustrate how this data could be used to target interventions across the whole catchment, the farms currently engaged in an Environmental Stewardship Scheme (ESS) have been overlaid on these areas of high P and SS pressures. These farms may be considered to represent an opportunity for the delivery of resource protection measures (either now or in the future) and the remaining areas could become priorities for ESS or other catchment management schemes in the future.

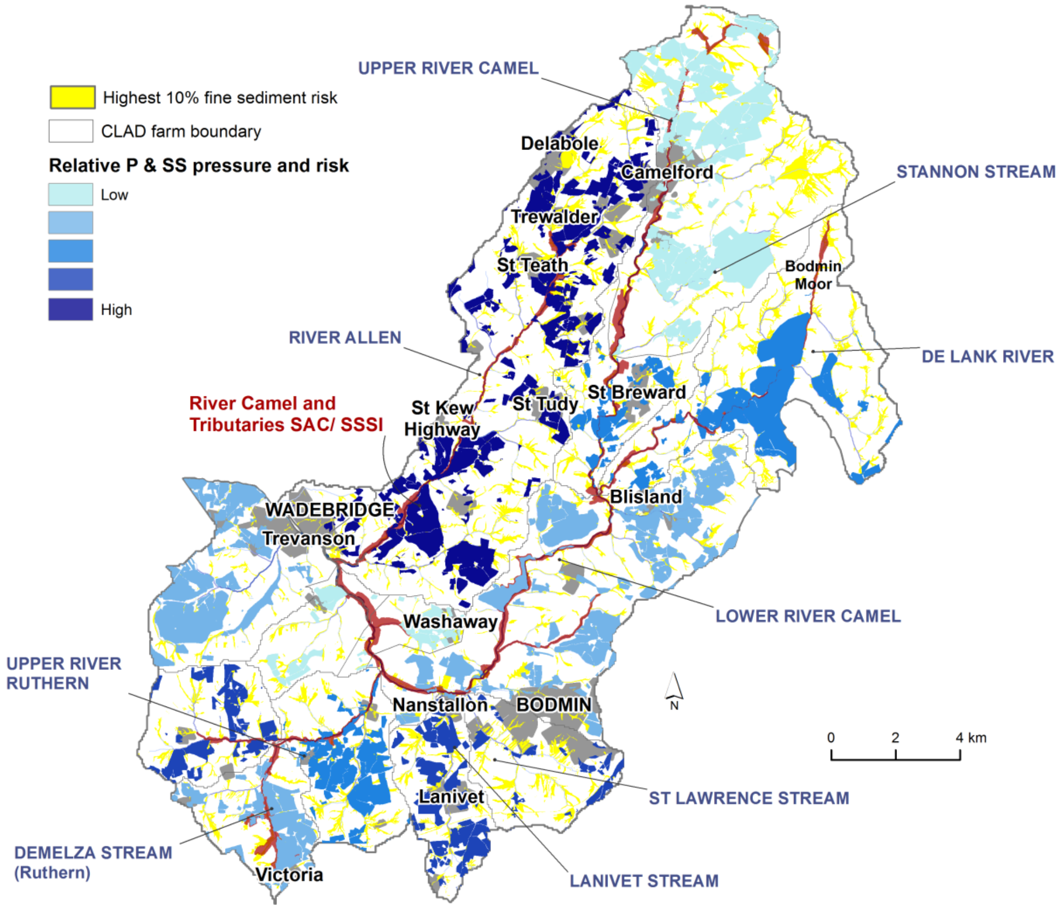
Ideally Catchment Sensitive Farming (CSF) information would be included to assess farms without CSF interventions. However, current CSF data was not available for this report.

Figure 36: *Relative sub-catchment P and SS pollution risk based on EA water quality monitoring, SAGIS, SIMCAT and SCIMAP outputs with ELS uptake.*



The intervention target map in Figure 37 highlights a number of farm clusters in the River Allen and Lanivet stream sub-cachments, which have high diffuse SRP and SS pressures. The identified high risk ares are not currently signed up to any ELS schemes.

Figure 37: *Intervention target farm locations and relative P and SS pollution.*



6.3. Deliverables and costs for proposed plan

In light of all of the findings of this investigation, a costed intervention plan has been developed as an illustration of what level of intervention may be required (Table 3). These estimates are purely based on the number of farms and, following further investigation and farm visits in the field, the numbers can easily be adjusted and any additional elements can easily be added to this structure if required. Locations for interventions should be targeted using the outputs from this report, specifically fine scale SCIMAP analysis, combined with walkover surveys and further sampling where necessary.

Table 3: *Approximate deliverables and costs for management in the Camel catchment. These are estimated numbers of deliverables based on the number of farms engaged, the uptake and average uptake. Costs are approximate and for guidance only.*

Advice & testing	**Output**	**Unit Cost (£000)**	**Total Cost (£000)**
- Farm planning/advisory visits including full farm survey, farm advisory plan & capital grant offer / negotiations	75		
- Septic tank management plans survey and advice programme for septic tank best practice and management	100		
- Soil tests including full soil assessment on each farm according to EA standard, documentation and follow-up	50	0.5	**25**
- Water chemistry monitoring weekly or bi-weekly samples at 6 locations for 2 years (yrs. 1 & 5)	624	0.125	**78**
Total			**103**

Investments	**Output**	**Unit Cost (£000)**	**Total Cost (£000)**
- Fencing riparian corridor fencing (kms)	50	5	**250**
- Farm infrastructure slurry storage, tracks and crossing points, major clean & dirty water separation, roofing etc.	50	25	**1,250**
- Minor infrastructure alternative drinking, troughs, pumps, clean and dirty water separation etc.	25	1.0	**25**
Total			**1,525**

*** HR, delivery costs and overheads are not included here and all costs are rough estimates based on previous delivery

7. Assessment of outcomes

It is vital to collect sufficient evidence to provide an objective and scientifically robust assessment of the effectiveness of interventions. Ultimately, the weight of evidence should be sufficient to be able to justify that interventions made across the landscape have either delivered significant improvements in water quality (and have therefore made significant contributions to the conservation status) and have generated significant secondary financial, ecological and social benefits.

A range of approaches can be used for a detailed assessment of the effectiveness of various outcomes delivered through catchment management work. This approach is designed to achieve the following objectives;

- ***Quantification of intervention delivery.*** Gather precise and detailed evidence of what has to be delivered, where it has been delivered, what it has cost and, perhaps most importantly, whether the intended outcome is for each.

- ***Monitor and evaluate environmental outcomes.*** Collect a comprehensive and robust set of data and evidence which demonstrates qualitatively and quantitatively that genuine improvements in water quality, and thus conservation status, have been acheived. In order to demonstrate the effectiveness of catchment management interventions, it is vital to collect baseline data (of the type presented in this report) and, in addition to temporal (before intervention) controls also explore the potential for some catchments/sub-catchments to form spatial controls. This approach should include a comprehensive evaluation of the current scientific literature relating to the likely outcomes achieved through the delivery of on-farm measures and the use of the most advanced modelling techniques which can be used to estimate the improvements in water quality that have been achieved.

- ***Monitor and evaluate secondary outcomes.*** In addition to demonstrating real improvements in water quality, an array of other outcomes can make considerable contributions to the conservation status of protected sites or towards other environmental or nature conservation targets. A number of monitoring and modelling approaches can be used to assess how catchment management can enhanced the provision of other ecosystem services across the catchment and to quantify the economic gains achieved by those engaged in the process.

7.1 Predicting outcomes: Farmscoper

Introduction

While the collection and collation of evidence for the environmental outcomes that can achieved through the delivery of catchment management interventions continues there are also a number of mathematical water quality models that can be used to predict the cumulative effects of implementing on-farm BFP measures at a catchment scale.

This section describes the results of the FARM Scale Optimisation of Pollutant Emission Reductions (FARMSCOPER) model, which was used to assess potential P and SS reduction scenarios in the Camel catchment, along with guidelines for post implementation assessments.

The FARMSCOPER model is a decision support tool that can be used to assess diffuse agricultural pollutant loads on a farm and quantify the impacts of farm pollutant control options on these pollutants (Zhang et al., 2012). FARMSCOPER allows for the creation of unique farming systems, based on combinations of livestock, cropping and manure management practices. The pollutants losses and impacts of mitigation scenarios can then be assessed for these farming systems.

FARMSCOPER uses input farm data and representative farm types to provide a baseline for diffuse agricultural pollutant emissions. The effect of potential mitigation methods are expressed as a percentage reduction in the pollutant loss from specific sources, areas or pathways.

The effectiveness of mitigation methods are characterised as a percentage reduction against the pollutant loss from a set of loss coordinates. The effectiveness values are based on a number of existing literature reviews, field data and expert judgement and are assumed to incorporate any effectiveness of implementation.

The effectiveness values for mitigation were allowed to take negative values, which represent 'pollutant swapping', where a reduction in one pollutant is associated with an increase in another. The tool also estimates potential consequences of mitigation implementation on biodiversity, water use and energy use.

Method

In this report, FARMSCOPER has been used to identify optimal mitigation scenarios quantify the potential reductions for agricultural P and SS pollution within the Camel catchment and selected sub-catchments. Agricultural Census returns for the Camel catchment in 2010 were used to develop a typical farm for the whole catchment. Finer scale FARMSCOPER analyses has also been run on the River Allen and Lanivet stream sub-catchments, as these are areas which have been identified as having high diffuse P and SS loads.

Other studies, such as Zhang et al. (2012), created a series of typical farm types within their catchment and multiplied the results by the number of farms for each type. As the Camel catchment is predominantly dairy farms, and dairy farms can produce high P loads, a single typical dairy farm for the Camel catchment and sub-catchments was considered most appropriate. A dairy farm was selected because the reductions associated which reduce P, which is a problem for the Camel, were more in-line with what would be expected when a dairy farm was selected. For instance, under a mixed farm, increased slurry storage did not show any reductions in P, however, these interventions would be important for catchment management of P in the Camel.

FARMSCOPER was used as the basis for testing three different scenarios and estimate the associated SS and P loads. The scenarios tested were:

- **Scenario 1:** Current emissions based on an estimate of the existing level of mitigation measures implemented. Current uptake was estimated based on local knowledge, ELS uptake and CSF interventions.
- **Scenario 2:** Maximum 100% uptake through implementation of optimised measures selected by FARMSCOPER.
- **Scenario 3:** 'Realistic' implementation measures based on local knowledge and 50% uptake of measures.

It should be noted that FARMSCOPER modelled costs detailed in this section, refer to the overall cost required to achieve the modelled reductions in pollutants, rather than a cost per area or time.

Results

Scenario 1

According to the FARMSCOPER baseline-emission apportionments; grassland (temporary grazing) and arable land supply a majority of P and SS pollution. In particular, dairy and beef provide a main source of SRP pollution via slurry and voiding; while soil erosion and transport are the main sources of SS pollution. The main pathway for all pollutants has been apportioned to preferential flow paths, followed by runoff (see Figure 38).

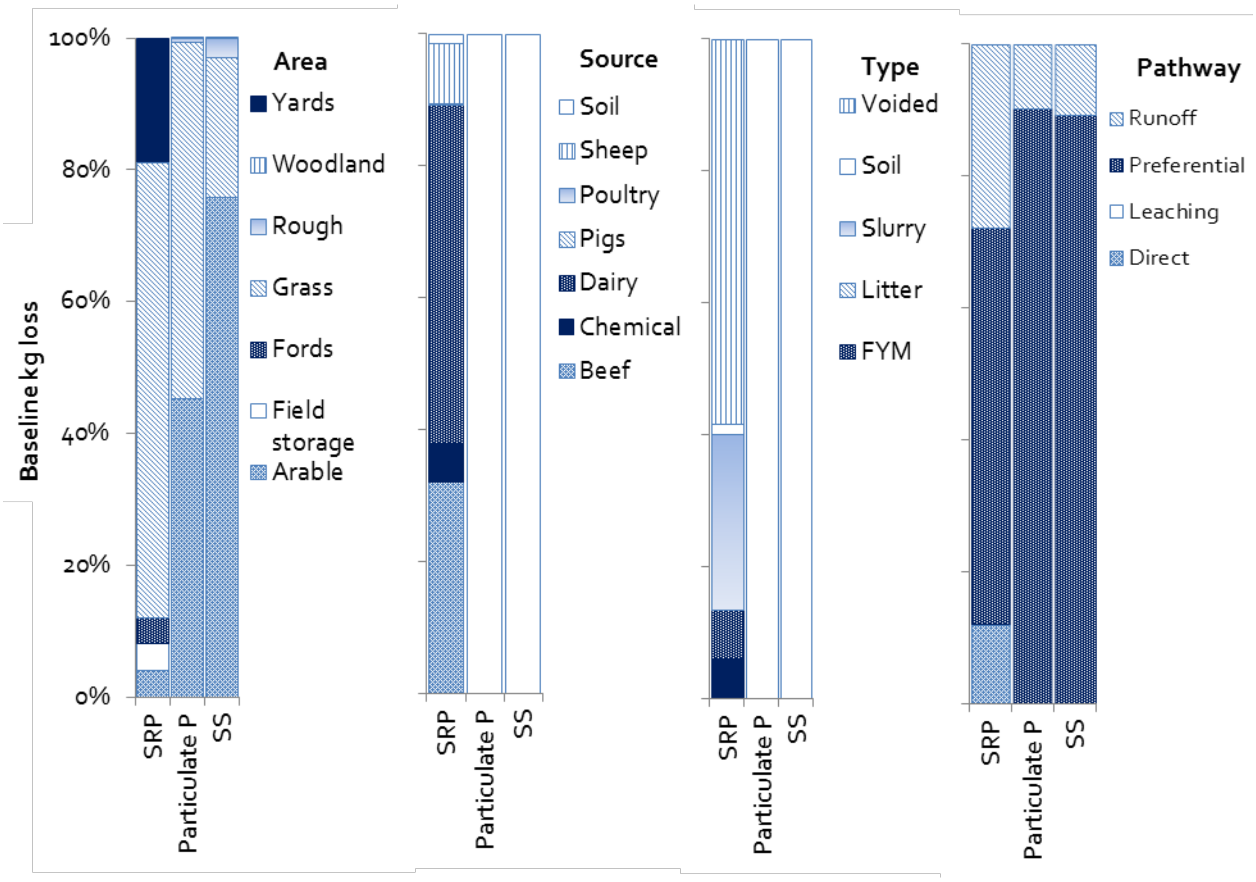
FARMSCOPER predicts baseline pollutant loadings in kg per hectare per year (kg ha^{-1} yr^{-1}) (Table 4).

A description of each intervention used in this FARMSCOPER optimised model are in Appendix 1.

Table 4: *FARMSCOPER modelled baseline P and SS loses (kg ha^{-1} yr^{-1}).*

		Camel catchment	River Allen	Lanivet stream
Area (ha)		31403	6581	1205
Loss kg ha^{-1} yr^{-1}	SRP	79,089	19,917	3474
	Particulate P	11,959	3138	427
	SS	9,559,640	1,989,809	347,226

Figure 38: *FARMSCOPER baseline P and SS source apportionment for the Camel catchment.*



Scenario 2

The maximum potential reduction scenario for SRP, particulate P and SS were modelled as 56, 15 and 10 % respectively for the Camel catchment. Higher potential reductions were found for sub-catchments, as has been show in previous research (Table 5) (Zhang et al., 2012).

The total cost for these mitigation methods for the Camel catchment has been estimated as £3,244,039 within FARMSCOPER. It is unrealistic that these maximum reductions could be achieved as the FARMSCOPER analysis was carried-out at catchment scale, using 68 methods, all set to 100% maximum implementation.

Whilst it may be possible to achieve greater reductions in P concentrations with higher intervention up-take rates, research and expert opinion suggest that around 15% reductions are realistic for P at the catchment scale, and 30% at a sub-catchment scale.

Table 5: *FARMSCOPER modelled maximum mitigation methods and scenario outputs defined by FARMSCOPER. Methods were set to 100% implementation.*

		Camel catchment	River Allen	Lanivet stream
Area (ha)		31403	6581	1205
Reduction kg ha^{-1} yr^{-1} (%)	**SRP**	44620 (56%)	11766 (57%)	1846 (57%)
	Particulate P	11813 (15%)	558 (23%)	112 (26%)
	SS	9, 55964 (10%)	324786 (16%)	59439 (17%)

Scenario 3

A more realistic but still intensive scenario implies that SRP, particulate P and SS could be reduced by up to 21, 5 and 19% respectively for an overall cost of £1,4 89,353 in the Camel catchment (table 6). FARMSCOPER predicts that these reductions would be possible if intervention methods were carried out in 50% of farms within the catchment. This scenario includes prior interventions which incorporated local knowledge to select methods which are considered best suited to address diffuse agricultural P and SS pollution in the Camel catchment, River Allen and Lanivet stream sub-catchments.

Selected implementation methods and the modelled % P and SS reduction and cost associated with each implementation method are detailed in table 7. P has not been divided into particulate and dissolved in table 7 because FARMSCOPER does not differentiate between these in the output. However, methods which contribute to particulate P reduction are usually those which contribute to SS reductions.

Along with P and SS reductions, the selected implementation methods can also benefit a number of other environmental factors. FARMSCOPER modelling has shown that the implementation of these methods would likely provide benefits for Ammonium, Nitrous Oxide (a greenhouse gas) and pesticide pollution, along with Biodiversity benefits. However, increased energy use has been predicted for implemented methods (table 8).

Table 6: *FARMSCOPER modelled realistic mitigation methods and scenario outputs defined by FARMSCOPER. Methods were set to 100% implementation.*

		Camel catchment	River Allen	Lanivet stream
Area (ha)		31403	6581	1205
Reduction kg ha^{-1} yr^{-1} (%)	**SRP**	16609 (21%)	4183 (22%)	730 (21%)
	Particulate P	598 (5%)	251 (8%)	38 (9%)
	SS	1816332 (19%)	716331 (36%)	145835(42%)

Table 7: *FARMSCOPER modelled 'realistic' mitigation methods and % reduction and FARMSCOPER cost estimate outputs.*

Mitigation method description	Camel catchment			River Allen			Lanivet stream		
	P % reduction	SS % reduction	Cost £000*	P % reduction	SS % reduction	Cost £000*	P % reduction	SS % reduction	Cost £000*
Establish cover crops in the autumn	2	13	72,489	3	26	29,733	4	32	6,246
Early harvesting and establishment of crops in the autumn	0	0	20,188	0	1	8,313	0	1	2,850
Establish in-field grass buffer strips	0	1	10,393	0	1	4,624	0	1	716
Loosen compacted soil layers in grassland fields	0	1	68,200	0	1	475	0	1	475
Increase the capacity of farm slurry stores to improve timing of slurry applications	1	0	169,902	1	0	48,461	1	0	8,578
Store solid manure heaps on an impermeable base and collect effluent	1	0	41,927	1	0	12,114	1	0	1,964
Do not spread slurry or poultry manure at high-risk times	3	0	11,740	3	0	3,293	3	0	541
Use slurry injection application techniques	6	0	234,794	6	0	65,859	6	0	10,823
Fence off rivers and streams from livestock	3	0	68,200	3	0	475	3	0	475
Re-site gateways away from high-risk areas	0	1	16,993	0	1	1,587	0	1	326
Establish and maintain artificial wetlands - steading runoff	4	0	213,660	4	0	61,058	4	0	9,966
Plant areas of farm with wild bird seed / nectar flower mixtures	0	2	214,199	0	1	17,644	0	1	3,776
Beetle banks	0	0	10,560	0	1	4,699	0	0	728
Take field corners out of management	0	0	50,288	0	1	22,376	0	0	3,465
Leave over winter stubbles	1	2	157,060	1	3	64,422	1	4	13,533
Capture of dirty water in a dirty water store	6	0	128,762	6	0	36,277	6	0	5,949
TOTAL	26	19	1,489,353	30	36	381,409	30	43	70,411

Table 8: *Impact of modelled 'realistic' mitigation methods and on other environmental components, values shown as % change per % in reduction in either SRP or SS. Negative values indicate and increase (highlighted in red) while positive values indicate a decrease, or positive effect (highlighted in green).*

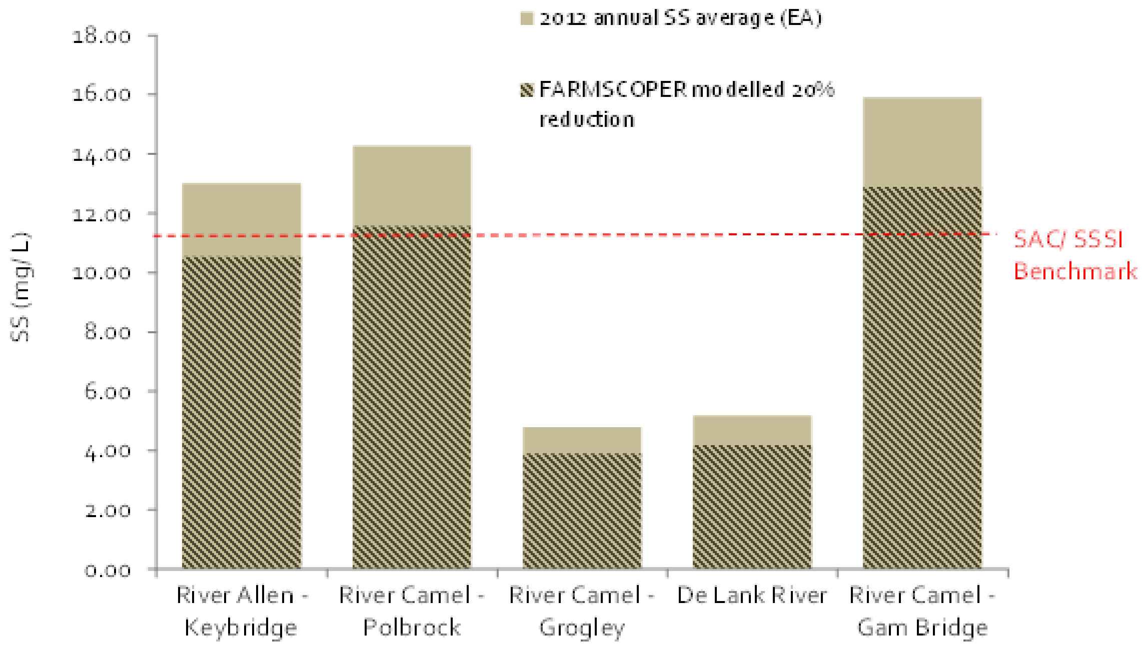
	Ammonia (%)		Nitrous Oxide (%)		Pesticides (%)		Biodiversity (Score)		Energy Use (Score)	
% change per 1 % reduction in:	**SRP**	**SS**	**SRP**	**SS**	**SRP**	**SS**	**SRP**	**SS**	**SRP**	**SS**
Mitigation method description:										
Establish cover crops in the autumn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Early harvesting and establishment of crops in the autumn	0.000	0.000	0.311	0.040	0.655	0.084	0.058	0.008	-0.730	-0.094
Establish in-field grass buffer strips	0.000	0.000	0.249	0.032	0.209	0.027	0.000	0.000	0.000	0.000
Loosen compacted soil layers in grassland fields	0.000	0.000	0.020	0.002	3.546	0.438	32.249	3.980	0.000	0.000
Increase the capacity of farm slurry stores to improve timing of slurry applications	0.000	0.000	0.903	0.149	8.588	1.420	0.000	0.000	-24.074	-3.980
Store solid manure heaps on an impermeable base and collect effluent	0.000	-0.234	0.065	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Do not spread slurry or poultry manure at high-risk times	0.000	0.000	1.112	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Use slurry injection application techniques	0.000	0.000	0.416	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fence off rivers and streams from livestock	0.000	1.392	0.075	0.000	0.000	0.000	0.000	0.000	-0.086	0.000
Re-site gateways away from high-risk areas	0.000	0.000	0.078	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Establish and maintain artificial wetlands - steading runoff	0.000	0.000	0.107	0.050	0.000	0.000	0.000	0.000	0.000	0.000
Plant areas of farm with wild bird seed / nectar flower mixtures	0.000	0.000	0.039	0.000	0.000	0.000	0.140	0.000	0.000	0.000
Beetle banks	0.000	0.000	0.020	0.005	0.752	0.185	6.744	1.657	0.270	0.066
Take field corners out of management	0.000	0.000	0.057	0.006	6.486	0.710	90.915	9.949	-3.637	-0.398
Leave over winter stubbles	0.000	0.000	0.057	0.006	6.486	0.710	45.458	4.975	18.183	1.990
Capture of dirty water in a dirty water store	0.000	0.000	0.199	0.064	0.419	0.135	2.336	0.751	-0.187	-0.060
TOTAL Change	0.00	1.16	3.79	0.35	27.14	3.71	177.90	21.32	-10.28	-2.48

Conclusion

FARMSCOPER modelling results suggest that application of on-farm measures across the Camel catchment can support wider measures, specifically point source management, to reduce P and SS concentrations to the required EQSs for the SAC/SSSI.

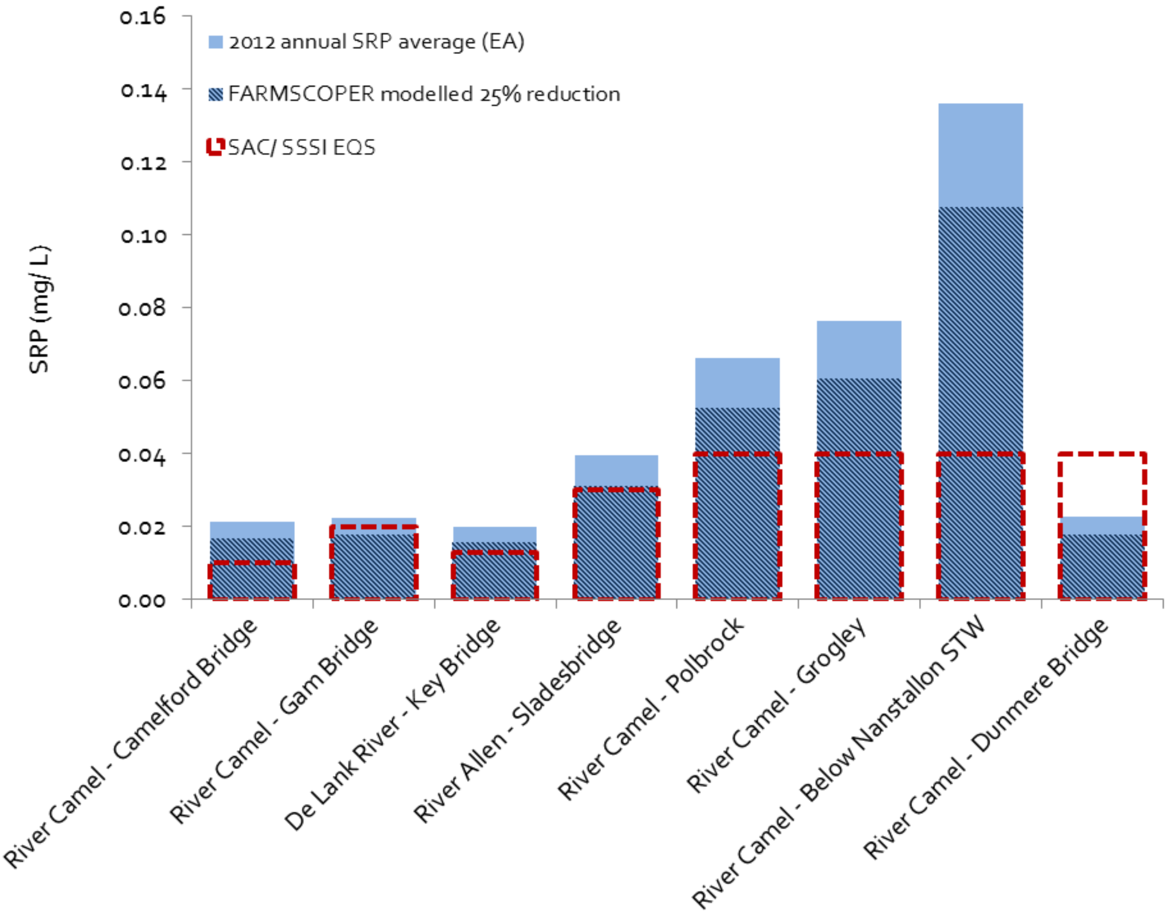
The modelled 'realistic' reduction of 19% for SSs would be sufficient to bring overall concentrations within SS benchmark used in this report for the SAC/SSSI (see Figure 39) in all sites except River Camel at Gam Bridge. However, FARMSCOPER results indicate, greater reductions can be achieved in smaller sub-catchments.It should be noted that environmental factors such as dry summers followed by heavy rainfall may still produce spikes in SS concentrations which are above the SS benchmark used in this report. For instance, the average SS concentration in the Camel SAC/SSSI may be increased above SAC/SSSI benchmark as a result of peak, rainfall driven concentrations.

Figure 39: *Predicted reductions in SS concentrations from FARMSCOPER analysis.*



These analyses show that, even following the reduction of agricultural nutrient sources, SRP would still exceed the EQS (0.04 – 0.06 mg/L) in the River Camel below Nanstallon STW in Bodmin. SAC/SSSI target concentrations in the Camel actually need to be reduced by up to 78%, whereas FARMSCOPER predicts maximum reductions of 21% for SRP (Figure 40). However, P stripping has been proposed for PR14 period 2014-2019, and SIMCAT modelling has shown that it will reduce SRP concentration in the lower Camel to around the SAC EQS. A moderate reduction in the agricultural diffuse source contribution and risk would therefore help ensure concentrations both fell and were maintained below the EQS..

***Figure 40:** Indication of potential reductions in SRP concentrations calculated from maximum FARMSCOPER reductions, modelled at 21%. Observed SRP concentrations are based on 2012 annual averages from EA WFD monitoring data.*



Limitations & assumptions

There are a number of limitations to the FARMSCOPER analysis used within this study which must be considered, summarised below:

- Cost estimates in FARMSCOPER are derived from a wide range of sources, specifically previous research projects, resulting in a number of assumptions that may not be directly applicable to farms in the Camel catchment.
- The AgCensus data was collected 4 years ago, livestock and cropping statistics for the Camel may have changed significantly during this time.
- AgCensus data is provided at an averaged 2km resolution, thus, farm scale land-use variability cannot be assessed.
- Prior implementation of mitigation methods has been estimated.
- Selected overall farm type, rainfall and soil characterisations at catchment and sub-catchment scale, overlooks smaller scale variabilities, leading to potential over and under estimations of pollutant emissions.

Due to limitations detailed above, the FARMSCOPER outputs within this study should be used to provide a coarse indication of potential SRP and SS reduction within the Camel catchment. However, the selected mitigation methods do provide some guidance of the most effective on-farm management options for P and SS, in-terms of cost and emission reductions.

Appendix 1: Optimised FARMSCOPER measures

Measure
Increase the capacity of farm slurry stores to improve timing of slurry applications
Minimise the volume of dirty water produced (sent to dirty water store)
Site solid manure heaps away from watercourses/field drains
Store solid manure heaps on an impermeable base and collect effluent
Cover solid manure stores with sheeting
Use liquid/solid manure separation techniques
Do not apply manure to high-risk areas
Do not spread slurry or poultry manure at high-risk times
Use slurry injection application techniques
Do not spread FYM to fields at high-risk times
Incorporate manure into the soil
Fence off rivers and streams from livestock
Construct bridges for livestock crossing rivers/streams
Re-site gateways away from high-risk areas
Farm track management
Establish new hedges
Protection of in-field trees
Management of in-field ponds
Unintensive hedge and ditch management on arable land
Unintensive hedge and ditch management on grassland
Management of field corners
Plant areas of farm with wild bird seed / nectar flower mixtures
Beetle banks
Uncropped cultivated margins
Uncropped cultivated areas
Unfertilised cereal headlands
Unharvested cereal headlands
Undersown spring cereals
Take field corners out of management
Leave over winter stubbles
Use correctly-inflated low ground pressure tyres on machinery
Locate out-wintered stock away from watercourses
Use dry-cleaning techniques to remove solid waste from yards prior to cleaning

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Further information & contacts

Angela Bartlett, Data and Evidence Officer, BSc. MSc.

Angela is an environmental scientist specialising in the technical delivery of strategic catchment management projects and in the communication of the Trust's scientific outputs to a wide variety of audiences.

Email: angela@wrt.org.uk

Dr Russell Smith, Consultancy Director, BSc. MSc. PhD.

Russell is a Chartered Scientist and Environmentalist and Consultancy Director for Westcountry Rivers Ltd. Russell has over 12 years' experience in catchment management/planning and environmental monitoring working in the public and private sector and has considerable experience in directing and managing diverse multi-discipline projects. Russell has been involved in the application and development of farm, catchment to national scale models and decision support tools since the late 1990's in both research and consultancy. His experience in integrated catchment modelling is complemented by his experience in monitoring and his detailed understanding of the relationship between temporally and spatially variable catchment processes.

Email: russell@wrt.org.uk

Dr Nick Paling, Head of GIS, Evidence and Communications, BSc. MSc. PhD.

Nick is an applied ecologist and conservation biologist with 8 years of experience using spatial techniques to inform conservation strategy development and catchment management. He provides data, mapping & modelling support for all Trust projects and coordinates and manages a number of large-scale monitoring programmes currently being undertaken by the Trust.

Email: nick@wrt.org.uk